SPECIAL photo section inside!

2009 Astroimaging Contest winners p. 56

September 2009

Astronomy®

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The day Earth came to life

In the past, non-living matter started to replicate itself. Scientists are still trying to figure out how. p. 24

Life on Earth may have started in a warm tidal pool, where organic molecules either homegrown or from space sparked a self-replicating system.

PLUS!

How astronauts made Hubble better than ever p. 36

The stars that revealed the vastness of the universe p. 48

What revved up the galaxy's hyperfast stars? p. 30

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Vol. 37 • Issue 9

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The Pillars of Creation (M16)
By Jim Wood (data) and Emanuele Colognato (processing).
Imaged with the LightBuckets .61m Ritchey-Chrétien (LB-0001) in Rodeo, NM. 117:60:60:60 minutes Hα, SII, Hα, and OIII respectively.

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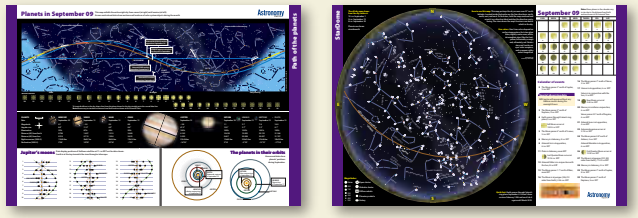

Path of the planets and StarDome.

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ON THE COVER

Life got its start early in Earth's history, perhaps in a tidal pool enriched with organic molecules produced by lightning bolts or delivered by comets or meteors.

Cover: Ron Miller for *Astronomy*

8 This Month in *Astronomy*
Celebrating great images of the sky.

10 Astro Confidential
Andrea Dupree, Don Figer, Bryan Gaensler, Amanda Hendrix, Deirdre Shoemaker

12 Letters
One telescope's true origin.

13 Web Talk

14 Strange Universe
Applying Occam's razor. **BOB BERMAN**

16 Evening Stars
The big brown nothing. **DAVID H. LEVY**

18 Astro News
Huge impact basin discovered on Mercury. Astronomers find a hidden supernova. Herschel and Planck on their way.

COVER STORY

24 The day Earth came to life
At some point in the dim past, non-living matter started to replicate itself. Scientists are still trying to figure out how. **JAMES TREFIL AND WANDA O'BRIEN-TREFIL**

30 What revved up the galaxy's hyperfast stars?
Since 2003 astronomers have found 16 stars escaping the Milky Way's gravity. The slingshot could be our galaxy's central black hole. **RAY JAYAWARDHANA**

36 A new day dawns for Hubble
Shuttle astronauts installed two new instruments, fixed two older ones, and upgraded the space telescope's gyroscopes and batteries. **RICHARD TALCOTT**

40 The Sky this Month
Uranus' turn in the Sun. **MARTIN RATCLIFFE AND ALISTER LING**

48 The stars that revealed the vastness of the universe
Cepheids are pulsating variable stars that astronomers use to measure cosmic distances. They remain at the heart of solving key cosmic riddles. **BRUCE DORMINEY**

54 Ask Astro
Why are galaxies so bright?

ASTROPHOTOGRAPHY SPECIAL

56 *Astronomy*'s 2009 Astroimaging Contest
Amateurs accepted the challenge and sent us these dazzling images. **MICHAEL E. BAKICH**

10 tips for beginning astroimagers
Use these techniques to produce celestial images you'll be proud to share with friends and relatives. **MICHAEL E. BAKICH**

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68 Secret Sky
Readers report 2009. **STEPHEN JAMES O'MEARA**

70 Observing Basics
Cruise the Milky Way. **GLENN CHAPLE**

72 New Products

74 Telescope Insider

75 Advertiser Index

79 Deep-sky Showcase

80 The Cosmic Grid

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Celebrating great images of the sky

by David J. Eicher

One of the most frustrating aspects of being an editor at *Astronomy* magazine is the incredible influx of beautiful images that come to us every day through e-mail or on CDs wedged into envelopes. There's an immense number of striking and high-quality shots, but we can publish only a tiny selection of the great stuff that's out there.

This frustration results from the good news — it's easier than ever to image the sky, whether it be shots of constellations, planets, galaxies, or nebulae. Amateur astronomy has never seen such a time so rich in great off-the-shelf equipment that allows skyshooters to capture their favorite targets with relative ease. Moreover, transformation of the darkroom into a few minutes' time in *Photoshop* has brought spectacular results even more within reach.

To celebrate the great state of amateur sky photography, *Astronomy* ran a 2009 Astroimaging Contest in which we invited readers to send us their best images in three categories: Deep Sky, Solar System, and General. Administered by Photo Editor Michael E. Bakich, our contest received submissions from astroimagers from the United States and many countries around the globe. The contest opened January 14 and closed April 15.

The grand-prize winner is Tony Hallas of Foresthill, California, for his magnificent image of the Andromeda Galaxy (M31). Tony put together several exposures of the galaxy made with a 14.5-inch scope and a 6-inch telescope, assembling all into what is surely the greatest amateur image of M31 ever produced. For his effort, Tony wins a 5-night stay at the Arizona Sky Village or Rancho Hidalgo Astronomy Village (worth $3,500), plus $1,000 to cover airfare, a rental car, and food. These two sites, operated by Gene Turner, offer some of the blackest skies in the United States.

Our Deep Sky winner is Rogelio Bernal Andreo of Sunnyvale, California, for his spectacular wide-field view of the region encompassing the Orion Nebula and the Horsehead Nebula. Andreo wins a set of 4 nebula filters from Lumicon worth $400.

The champion of the Solar System category, Damian Peach of Buckinghamshire, England, captured Jupiter and moons Ganymede and Io in stunning detail. Astrodon Filters provided Damian's prize, a mounted 1¼" Hydrogen-alpha filter worth $275.

Our winner in the General class is Anthony Ayiomamitis of Athens, Greece, who created a terrific image of a moonrise over the Temple of Poseidon in Sounion, Greece. Anthony wins a 13mm Ethos eyepiece from Tele Vue worth $620.

Thanks to all who submitted pictures, many of which you'll see in future issues if not in this one, and to the companies who provided the prizes. To see the winners, turn to our special section on page 56, "*Astronomy*'s 2009 Astroimaging Contest," which also presents 15 other pictures submitted in the competition. These additional images are spectacular in their own right. You'll enjoy Ryan M. Hannahoe's gorgeous images of the Eta Carinae Nebula. Greg Piepol's Hydrogen-alpha image of the Sun is terrific. And you'll marvel at Paolo Lazzarotti's image of the Moon's south polar region. Enjoy!

Yours truly,

David J. Eicher
Editor

Astronomy

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by Karri Ferron

OUR TURN

Andrea **Dupree**

Senior astrophysicist at the Smithsonian Astrophysical Observatory, Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts

Why did you choose astronomy for a career?

My choice of astronomy was truly accidental. My liberal arts college, Wellesley College, required that every student take a laboratory science course.

To me, college was the time to try out new fields. Looking through the Wellesley College course catalog, I found only two unfamiliar laboratory science subjects that fulfilled the laboratory requirement: astronomy and geology.

So the summer before my freshman year, I flipped a coin to make the choice — and it came up astronomy. At Wellesley, I discovered that astronomy is a "practical" combination of both physics and math applied to the universe — and I loved it!

What's going on in your research of cool stars?

Cool-star research is now bubbling with new ideas. This includes discoveries of planets — sometimes many planets — around cool stars.

These systems are vastly different from our solar system and stretch our concepts of systems of stars and planets. How did the stars form? Where and when did the planets form? How did their sizes and arrangements come to be? How does the stellar history affect the planets? How do the planets affect their host stars? All of these questions impact our understanding of Earth's history, including the evolution of life on it.

What was a challenge you faced in your career, and how did you respond?

In the late 1970s, issues of salary inequality began to emerge in scientific communities. I discovered that my salary was substantially less than a male colleague of about the same status. Before bringing this inequity up with my supervisor, I gathered data. How many papers had he published? How many talks had he given? I clearly had more accomplishments than my colleague. So why was my salary 30 percent lower?

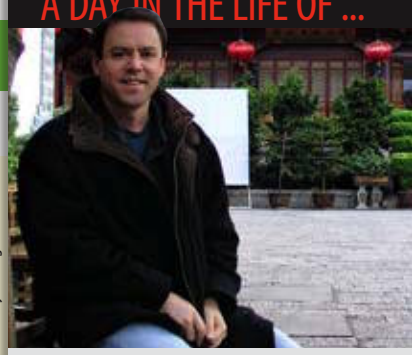
I went to see my supervisor and showed him what I had found. He smiled kindly and offered an explanation: I had a husband to support me, so I did not need the money. Obviously, not a satisfactory answer. So I went to see the Division Director, who found my comparison interesting and said he would be happy to look into this the following year when the annual salary reviews were scheduled.

A year is a long time for inequities, so I spoke with the Observatory Director. He reviewed the situation and increased my salary immediately. In this case, factual evidence coupled with persistence led to a satisfactory conclusion.

Images courtesy Andrea Dupree

To learn more about people featured this month, visit www.Astronomy.com/toc.

A DAY IN THE LIFE OF ...



Courtesy Don Figer

Don **Figer**

Director of the Rochester Imaging Detector Laboratory (RIDL) and professor at the Rochester Institute of Technology (RIT) in New York

- **8 A.M.** Watch daughter board the school bus, and then get in my own school "bus" to go to RIT.
- **9 A.M.** Prepare lecture for undergraduate Detectors course.
- **10 A.M.** Meet with students during office hours.
- **11 A.M.** Finish paper describing the discovery of a massive star cluster in the Milky Way.
- **Noon** Have lunch on campus with RIDL co-workers.
- **1 P.M.** Write data reduction and analysis software for the NASA-funded low-noise detector project in the RIDL. This $1.7 million project will develop a new generation of low-noise detectors for astrophysics and planetary space missions.
- **2 P.M.** Write first draft of proposal for funds to create the National Center for Imaging Detectors.
- **3 P.M.** Attend weekly RIT Massive Star research group meeting.
- **4 P.M.** Meet in RIDL to discuss single-photon imaging detector project for the Thirty Meter Telescope, funded by the Gordon and Betty Moore Foundation. This $2.8 million project will develop a new detector that will quadruple the power of a telescope for detecting the faintest objects in the universe.
- **6 P.M.** Have dinner with family and recount favorite things that happened today.
- **7 P.M.** Tuck girls into bed.
- **8 P.M.** Review draft papers from astronomers in the Massive Star research group.
- **9 P.M.** Review NASA research proposals and referee paper for *The Astrophysical Journal*.
- **11 P.M.** Count my lucky stars until I fall asleep!

Astro**insights** *Where is astronomy headed?*

For centuries, astronomers have used the "point and shoot" approach: We pick some interesting objects, aim our telescope, and generate a series of images on which we base calculations and develop new ideas.

The more ambitious projects are surveys — efforts to map out huge swaths of the sky, lasting years or decades. Foundations of modern astronomy have come from such efforts. Astronomers usually perform a survey through a scaled-up version of "point and shoot": We take a huge number of individual small images and stitch them together to produce a panorama of the sky.

New technologies are about to change everything. In the next decade, new telescopes like the optical Large Synoptic Survey Telescope and the radio Square Kilometer Array will use the equivalent of fish-eye lenses to image huge strips of the sky in a single exposure. The resulting amount of data will be incredible.

The challenge astronomers will face is how to extract useful information from this vast torrent. But the incentive is that new types of astronomy will become possible. We will be able to scan the entire sky every night, looking for unusual transient objects like gamma-ray bursts, or perhaps even signals from extraterrestrial civilizations. We will be able to search the observable universe for the subtle signatures of dark energy and intergalactic magnetism. And with new catalogs of stars and galaxies a million times larger than before, we will discover rare and bizarre objects that will open up entire new fields of study. The data revolution is coming.

Bryan **Gaensler**

Australian Research Council Federation Fellow and professor of physics at the University of Sydney

Laurie Swope

Astro**ideas**

What is making waves in gravity?

The study of gravitational physics covers a broad range of scales, from an apple falling from a tree to the collapse of a massive star into a black hole. Modern research in gravity echoes these scales by encompassing both the quest for a quantum theory of gravity and the study of the formation and evolution of the universe.

While gravitational physics has long been an exciting topic, with popular figures like Albert Einstein and intriguing notions like warped space-time, it's on the verge of entering a new era driven by observation. The observations are designed to detect gravitational waves — fluctuations of space-time caused by masses in motion — for the first time. Gravitational waves offer an unprecedented view into the electromagnetically obscured regions of space, including centers of galaxies and interiors of energetic phenomena such as gamma-ray bursts.

One crucial component of detecting gravitational waves is making a forecast of what we expect to see using gravitational-wave detecting instruments. Fortunately, our understanding of Einstein's theory of gravity is rapidly increasing. This allows us to predict the unique pattern of gravitational waves from the strongest sources, like binary black hole and neutron star systems.

We should hear about the detection and interpretation of gravitational waves within the next several years by observatories like the Laser Interferometer Gravitational Wave Observatory and the Laser Interferometer Space Antenna mission. These observatories will read messages encoded on gravitational waves, and astronomers will combine the data with information from electromagnetic observations. It will fuel a new kind of multi-messenger astronomy.

Courtesy Deirdre Shoemaker; background: Chris Henze (NASA)

Deirdre **Shoemaker**

Assistant professor of physics at the Georgia Institute of Technology in Atlanta

Astro**influences**

How did you get interested in astronomy?

I might have been born interested in astronomy because I don't recall a particular defining moment when I decided that this was the field for me. I remember learning about the solar system in second grade and loving it. And I was fascinated by Viking lander images in the *Los Angeles Times*.

Growing up not too far from JPL, I thought they did the coolest stuff and wondered how someone got a job there. But I don't know if I ever thought it was really going to happen to me.

My primary interest now is studying moons and other small bodies in our solar system. I got into this field with some luck and intuition. I made my way through college and graduate school studying engineering, looking for the field that really felt right to me.

As a grad student, I did an internship at JPL with the navigation team for Galileo, the spacecraft that at that time was en route to Jupiter. That really opened my eyes to the field of planetary science, and I realized that I wanted to study the planets more than I wanted to work on spacecraft engineering.

As a postdoctoral researcher, I studied the moons of Jupiter using Galileo data. Now I'm busy studying the moons of Saturn using data from the Cassini spacecraft and having great fun!

Courtesy Amanda Hendrix

Amanda **Hendrix**

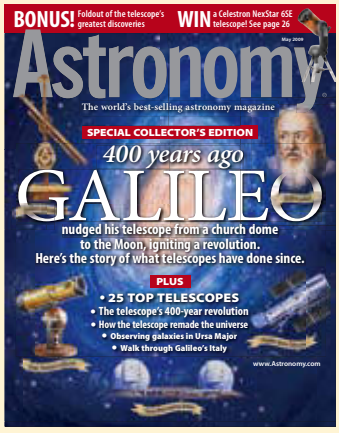
Planetary scientist at the Jet Propulsion Laboratory (JPL) in Pasadena, California

One scope's story

I greatly enjoyed Liz Kruesi's article "The telescope's 400-year revolution" (May). Indeed, the whole May issue is very good. Please allow me, however, to add some information: that Alvan Clark did not make the 18.5-inch refractor for the Old University of Chicago. It was delivered to Chicago, but Clark made it for the University of Mississippi from glass blanks that the university's chancellor, Frederick Augustus Porter Barnard, obtained in Europe.

The University of Mississippi — now affectionately called Ole Miss — ordered the telescope with the desire to have the largest refractor in the world. Some sources claim that Barnard had to talk Clark into attempting the project that, when successful, led Clark to make even larger lenses, such as the 26-inch for the United States Naval Observatory.

Sadly, when Clark finished the 18.5-inch instrument in 1862, the country was in the throes of the Civil War; the university couldn't pay its debts and was closed, and delivery to Mississippi was impossible. So, the telescope went to Chicago. It would be many years before the University of Mississippi could afford another large refractor — a 15-inch.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The May issue of *Astronomy* featured numerous articles about the telescope's history. Cover image: Robb Helf

Using that instrument (as a young boy in 1959), I saw Jupiter and its moons. That sight led me to major in physics (at Ole Miss) and pursue a career as a physics and astronomy teacher and continue my interest as an amateur astronomer. The college where I now work has a 14-inch Celestron, and one of our hopes is that young people will be as inspired by looking through it as I was that summer night long ago. **— John A. Grant, Jr.,** Pearl River Community College, Poplarville, Mississippi

An issue to be proud of

In the April issue, the ongoing efforts to reinvent the publication with new blood and pristine and logical graphics combine with a renewed commitment to science as well as the needs of the observer. The result is so satisfying to this subscriber! The entire team should be proud. You have my thanks for taking the magazine to this new level.

Within department after department (such as "Astro Confidential," where three out of five profiles are of women scientists — Brava!), the issue unfolded knowledge, tips, tricks, updates, and all the necessary observing info I've come to count on from *Astronomy*. And, again, this content has never looked better or been more accessible.

Then, there were three (count 'em, THREE) major cosmology articles of the most thought-provoking and insightful content that I've had the pleasure to read in some time.

Oh, and the addition of David Levy as a columnist starting in June? Well, that's just the cherry on the icing on the cake! **— Dave McCauley,** Granite Falls, Washington

Reacting to no beginning

Kudos and thanks to Paul J. Steinhardt and his associates for "Why the universe had no beginning" (April). I've been looking forward to this article for many years. The notion that the Big Bang just suddenly happened has always bothered me. Something enormous must have led up to this event, and finally scientists have a theory. Of course, a cyclic universe probably poses more questions than answers, but hopefully it leads us in the right direction. **— Andy Werback,** San Jose, California

Advance notice appreciated

Thanks for the heads-up about the Venus/Moon occultation event April 22. I usually pass on these kinds of events because of my luck with clouds being around, or just being in the wrong location at the right time. I am 600 miles east of the optimum observing line for this event — near the Texas/Louisiana border. But it was clear as a bell, and the Moon and Venus were just bright enough to see despite a very bright Sun and sky at 7:45 A.M. With binoculars, co-workers and I witnessed Venus fade behind the Moon's lower limb. And it didn't take long either. About 15 minutes later, Venus reappeared from the bottom dark side of the Moon as if flipped on by a switch. It brought "wows" not only from me (I keep tabs on astronomy events) but also from my co-workers, who now have a deeper appreciation for things "up above." **— Roy Platt,** Timpson, Texas

Corrections

On page 38 in the April issue, star cluster NGC 2365 should be NGC 2362.

In May's pullout poster, "Scoping out the great discoveries," for the year 1846 the second sentence should read, "John Couch Adams and Urbain Leverrier calculate the object's position based on the gravitational perturbations of Uranus."

A caption on page 44 of the June issue misidentified a volcano on Mars as Olympus Mons. The volcano is actually Elysium Mons. **— *Astronomy* editors**

We welcome your comments. Send letters to Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

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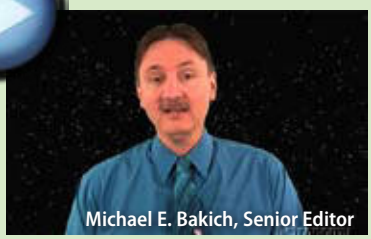

Featured video

"Autumn observing targets for small telescopes"
Astronomy magazine Senior Editor Michael E. Bakich highlights the objects you can see this fall using a small telescope.

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Senior Editor Michael E. Bakich's weekly series helps you find three notable objects or sky events you can see.

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Strange Universe

by Bob Berman

Applying Occam's razor

Problem solving isn't always a clean shave.

"What's going on here?" muttered astronomer Barry Madore, half to himself and half to me, as we stared at strange filaments oozing from the galaxy M82. It was weird, all right. The brand new image from the colossal 6.5-meter Magellan telescope in Chile showed thin feathery strands streaming out from the galaxy's edges.

Researchers see all sorts of puzzling things. Solving a problem in science — or in everyday life — starts with a logical guess. Sometimes two or more explanations seem plausible. How do researchers choose among the options?

Franciscan friar William of Ockham came up with an effective procedure back in the 14th century. He said, in essence, that the simplest explanation is usually the correct one.

Today this method of choosing from a host of possibilities is called Occam's razor.* You use it all the time. If your car won't start in the morning, you probably first think, "Maybe the battery is dead; I could have left a light on." Sure, it's possible an overnight meteor destroyed the car's electronic ignition. And there's a chance someone from the CIA disabled the vehicle to keep you from getting to your appointment. But few of us would start there. We begin with the battery, and we usually solve the problem quickly.

Awhile ago, I switched on a table light only to find it didn't work. I checked the plug, then the switch. The switch seemed a bit loose, so I took it apart. Rewired it. Bob's not so smart. If I had used Occam's razor, I would have simply changed the bulb and saved all that wasted time.

Medical schools routinely advise interns to use Occam's razor: "If you hear hoofbeats, think horses, not zebras."

This is where pseudoscience goes wrong. Paranoid web sites attribute common phenomena to complex conspiracies rather than simple explanations. Case in point: those white lines following jets across the sky. On a recent radio show, a caller asked if I was aware that the government is spraying poisons on us from planes. Later I learned that many people think the substance trailing behind jets is a deliberate chemical release. They call those long, widening clouds "chemtrails."

Having observed them since I was a kid and being an airplane owner myself, I know they're just "contrails," which vary their appearance with temperature and humidity. Burning jet fuel (kerosene) releases water vapor, which in very cold air freezes into long white pencil clouds that can widen dramatically. People have observed them since 1930. But instead of this simple explanation, the conspiracy web sites think the phenomenon started only a decade ago and involves an evil scheme in which 40,000 commercial pilots and air traffic controllers are in on the plot to poison their own children.

Solving a problem in science — or in everyday life — starts with a logical guess.

Many of us are gullible like that. For a while I actually believed the TV diet ads and imagined I could stop doubling my mass every 100 days. But scientists can't afford to be so ingenuous; they want to get to the bottom of mysteries, fast. So when astronomers at NASA's Jet Propulsion Laboratory in Pasadena, California, first observed straight lines on the surface of the jovian moon Europa in 1979, their initial hunch wasn't "runways built by aliens for their mother ships." No, they started with: "Looks like cracks in ice."

When seeking truth, a helpful companion to Occam's razor is the principle that extraordinary claims require extraordinary proof. For example, generations of scientists believed animal extinctions happen slowly. Then in 1980, father and son Luis and Walter Alvarez said the dinosaurs all died suddenly thanks to a meteor impact. This was an extraordinary claim! But they had the extraordinary proof.

Venturing around the world, they'd found sediment layers from 65 million years ago to be oddly rich in iridium and osmium. These elements are rare on Earth but common in meteorites. Bingo! Thick dust from an impact must have hung in the air and rained down over the planet. The dramatic theory was quickly accepted.

But back in Chile that cold night 3 years ago, Barry Madore asked me, "Where is Occam's razor here?" We gazed at the image. The galaxy's outer material spread out wildly, defying logic. Does gravity weaken in a way never before suspected? Or was some unknown dark matter yanking on those millions of suns? He shook his head. "What do you choose here — the improbable or the exotic?"

The reason for his torment was clear enough. Like many astrophysicists today, he was staring at a place where no explanation was simple or familiar.

He trusted Occam's razor. But in those distant hallways of the universe, 10 million light-years away, Occam's razor was nowhere to be found.

**It's no typo. William was from Ockham but the razor is spelled Occam.*

Find more of my strange universe at **skymanbob.com.**

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Evening Stars
by David H. Levy

The big brown nothing

When Earth's most extreme tides are low, the water level drops 50 feet. This leaves a lot of brown mud.

"What is that thing out there?" my wife Wendee asked anxiously while she looked out the north-facing window of our guest room in Nova Scotia. Our host and friend, physics professor Roy Bishop, needed details. "What thing? Is it an animal?"

"No, it isn't!" Wendee answered abruptly. "It's a geological thing." Waving her arms for emphasis, she added, "It's a big brown nothing!"

Just a few hours earlier, Wendee had noticed a vast expanse of water stretching from the shore a few feet away from where we were staying all the way to the northern horizon. Now all the water was gone. In its place was a colossal amount of brown mud — truly a big brown nothing.

The vertical water level in Minas Basin of the Bay of Fundy changes dramatically depending on low or high tide. Here the basin is at high tide, and ice flows in the cold water. David H. Levy

This was Wendee's introduction to some of the most extreme tides on our planet — those at the Bay of Fundy. Later that week, we made two visits to Bishop's birthplace, the village of Hantsport, Nova Scotia, to learn more about the tides. Hantsport sits on the bank of the Avon River, which feeds into the Minas Basin and eventually the bay.

During our first trip, the tide was out and a large ocean-going tugboat was resting at the wharf, its wooden keel deeply dug into the mud. Five hours later, when we returned near sunset, the tugboat had departed. Now fully afloat in deep salt water, it was towing a ship laden with gypsum out of the basin.

The Fundy tides are among the highest in the world. At Hantsport — one of the most inland parts of the bay — the vertical tidal range can exceed 50 feet (15 meters) in 6 hours. For that much water to pass through, the tidal current roars out of the Bay of Fundy and rips through the Minas Channel at about 11 mph (18 km/h). In 6 hours, more than the combined total of water flowing through every river on Earth flows through the channel.

On two occasions, I hiked up North Mountain from the village of Scott's Bay, and then headed east to Cape Split. Almost an hour before arriving, I began to hear the roar of the water hurtling through Minas Channel.

What causes the extreme rumble? It's a combination of the gravitational tug that the Moon exerts on Earth's waters and tidal resonance. The amount of time it takes a large wave to travel from the bay's mouth to the opposite shore and back is the same as the time between high and low tides. So the movement of the water in the bay becomes synchronized with the lunar tides.

The roar continued for another 3 hours or so as the waters surged through the channel into Minas Basin, where they began to fill the rivers and flow into other parts of Nova Scotia. Then the flow stopped, and all was quiet for just a moment. The whole process reversed, with tidal waters flowing out.

At some good vantage points, another magnificent effect becomes evident: As the fresh river waters push their way toward the basin, a rush of salt water pushing in the opposite direction overtakes them. These events are called tidal bores, and their appearance can be timed to the minute.

Tides are not a phenomenon only on Earth; they involve any pair of bodies in a solar system. On July 7, 1992, Comet Shoemaker-Levy 9 passed within about 15,000 miles (24,000 km) of Jupiter's cloud tops. The gravity between them was about 200 times that between the Moon and Earth — more than sufficient to break the comet into 21 pieces.

I used to enjoy hiking along the dikes that snake along the northern Nova Scotia coast when the tide was nearly out, especially on a moonlit night. The Acadian population built the dikes to keep the mighty Fundy waters from contaminating the rich farmland to the south. As I gazed upward, I could visualize the Moon's gravity at work, gently causing the waters to flow inward along the rivers of northern Nova Scotia, then outward back toward the bay.

Usually you can't be in a hurry when you watch nature work. (An event like a star igniting can take 200 million years.) But the interplay of the Moon and Earth happens rapidly here, so it can be enjoyed in a few hours. Watching the twice-daily water surge is a real treat that allows us to see how a distant object in space can gently, inexorably, affect life on Earth.

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Modern game theory—the scientific study of interactive, rational decision making—is instrumental in helping us understand how and why we make decisions. Game theory plays a crucial role in our lives and provides startling insights into all endeavors in which humans cooperate or compete, including biology, politics, and—most importantly—economics.

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Professor Stevens introduces you to several of game theory's classic games, including Chicken, Stag Hunt, and the Prisoner's Dilemma. He translates these games into everyday examples, turning them into gateways to game theory's most important and exciting ideas. You also study how game theory applies to areas such as business and war, and investigate the innovative theories developed by its greatest minds.

While game theory is rooted in mathematics, these lectures require only a basic understanding of how numbers operate and interact. Every lecture in **Games People Play** features visually rich graphics that enable you to grasp the simple mathematics behind this fascinating field.

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About Your Professor

Dr. Scott P. Stevens is Professor of Computer Information Systems and Management Science at James Madison University, where he has taught for over 20 years. He received his Ph.D. in Mathematics from The Pennsylvania State University. A frequent consultant in the business arena, Professor Stevens has been honored repeatedly for his remarkable teaching abilities.

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The wide view IMAX 3-D cameras captured the fifth and final servicing mission to the Hubble Space Telescope May 11–24.

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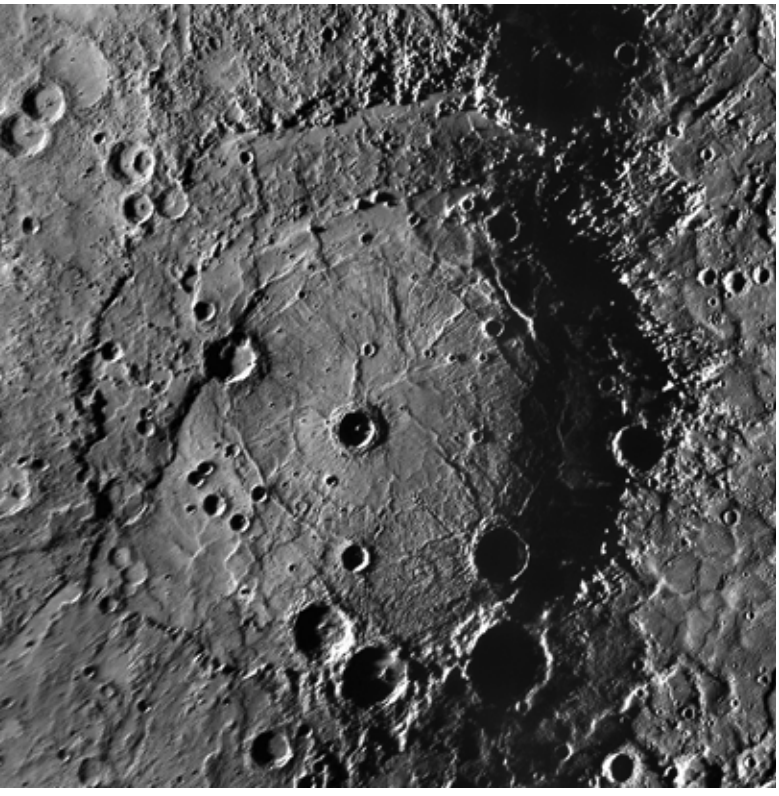


Giant blast. The well-preserved Rembrandt Basin, discovered during MESSENGER's second flyby of Mercury in October 2008, is the second-largest basin known on the planet. It measures 445 miles (715 kilometers) in diameter. NASA/JHUAPL/SI/CIW

Huge impact basin discovered on Mercury

When the MESSENGER spacecraft flew past Mercury October 6, 2008, its cameras revealed parts of the innermost planet never seen before. Lurking in this unexplored region is an impact basin measuring about 445 miles across (715 kilometers), making it the second-largest basin on Mercury.

Named Rembrandt, the site doesn't show the effects of age as much as most of Mercury's basins. The structure formed about 3.9 billion years ago, near the same time as the much larger Caloris Basin and near the end of the heavy bombardment that pummeled the inner solar system.

"Although ancient, the Rembrandt Basin is younger than most other impact basins on Mercury," says Thomas Watters of the Smithsonian Institution in Washington, D.C. Watters' research team reported its findings in the May 1 issue of *Science*.

"This is the first time we've seen terrain exposed on the floor of an impact basin on Mercury that is preserved from when it formed," says Watters. "Landforms such as those on the floor of Rembrandt are usually completely buried by volcanic flows."

Scientists will see Rembrandt again when the MESSENGER spacecraft flies past Mercury September 29. This flyby will be the final dress rehearsal before the probe starts to orbit the planet in March 2011. — **RICHARD TALCOTT**

20 Astronomers find a hidden supernova

21 Spitzer warms up

22 Rover spies young crater

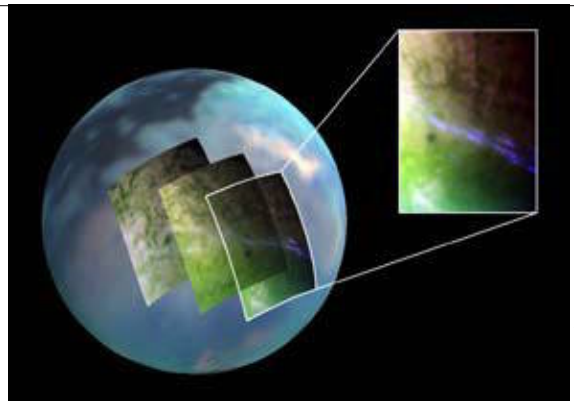
23 Herschel and Planck on their way

Indian summer on Titan

Summer clouds are hanging around longer into the fall on Saturn's moon Titan than scientists would have predicted. The scientists have monitored some 200 clouds in the icy moon's southern hemisphere from July 2004 to December 2007.

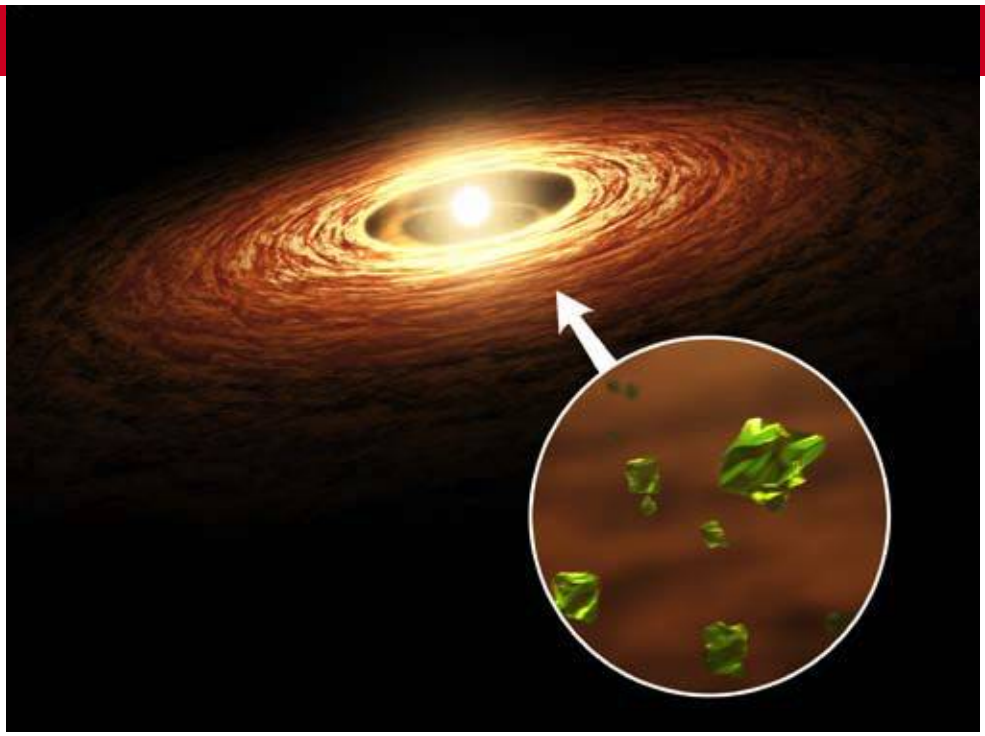
"Titan's clouds don't move with the seasons exactly as we expected," says Cassini mission researcher Sébastien Rodriguez of the University of Paris Diderot. "We see lots of clouds during the summer in the southern hemisphere, and this summer weather seems to last into the early fall." The study appeared in the June 4 *Nature*.

Cassini scientists will continue to observe the cloud cover on Titan through Earth's fall in 2010. — **LIZ KRUESI**



University of Arizona/LPL

Slow moving. Patchy clouds hover over the saturnian moon Titan's southern hemisphere. The clouds move more slowly than expected and should have disappeared by now.



Creating crystals. In this illustration, a star's outburst increases the temperature in its surrounding gas and dust disk. The high temperature changes amorphous silicate into silicate crystals. NASA/JPL-Caltech/T. Pyle (SSC)

Stellar outbursts can create comet crystals

Astronomers may have figured out how silicate crystals — which need hot temperatures to form — end up in comets living at the solar system's cold outer edge. Such crystals appear to form when a young Sun-like star undergoes an outburst and heats shapeless material (amorphous dust) in its inner planet-forming dust disk. Two articles appeared in the May 14 *Nature*.

A team of astronomers, led by Péter Ábrahám of the Konkoly Observatory of the Hungarian Academy of Sciences, studied the light signature of the young star EX Lupi as it flared in April 2008. The team compared that light signature with another of the star obtained in 2005 and found new silicate crystal features in the 2008 light of the dust disk surrounding the star. The researchers think that as the star flared, it heated the amorphous dust in the disk to a temperature that changes the material into crystalline form. One *Nature* paper discussed their results.

Scientists have evidence about how these silicate crystals form, so how do they get to the outer solar system? Dejan Vinković, in the second *Nature* article, suggests that the dusty disk's radiation combined with radiation pressure from the star could push the silicate crystals above the disk and then toward the outer edge. Once the crystals reach the cold outer regions, they experience less radiation pressure, and they fall back into the disk. **— L. K.**

BRIEFCASE

Most distant star blast

Astronomers have spotted the most distant blast ever. The gamma-ray burst (GRB), triggered by the collapse of a massive star, occurred some 13 billion light-years from Earth. NASA's Swift satellite detected the radiation blast, dubbed GRB 090423, April 23. The record-breaking explosion occurred when the universe was only 630 million years old, a mere one-twentieth of its current age. — L. K.

Kepler begins staring contest

As of mid-May, NASA's Kepler mission has officially begun its search for earthlike worlds. The craft launched March 6, and scientists and engineers spent the following 2 months calibrating and checking it out. As a planet passes in front of (or "transits") its sun, the planet blocks starlight. During the next 3.5 years, Kepler will stare at the same patch of sky and 100,000 stars, looking for periodic dips in starlight. — L. K.

Black hole ghost

A supermassive black hole produced a large amount of radiation when it erupted about 3 billion years after the Big Bang. Most of that radiation has since faded away, but electrons from the eruption interacted with material to produce radiation in the form of X-rays. Now astronomers at the Chandra X-ray Observatory have observed those reborn X-rays as a "ghost" of the black hole's past. Their findings will appear in the *Monthly Notices of the Royal Astronomical Society*. — L. K.

QUICK TAKES

MYSTERY STAR
A long-lived, X-ray emitting flare-up in 2006 was the supernova explosion of a carbon-rich star, astronomers reported June 2.

GODDARD'S ANNIVERSARY
Fifty years ago May 1, the Beltsville Space Center officially became NASA's Goddard Space Flight Center, the agency's largest center for astronomy and space science.

ATACAMA ATTABOY
On April 30, astronomers linked the first two antennas in the Atacama Large Millimeter/submillimeter Array (ALMA), a radio telescope being built in Chile.

CHUTING FOR SPACE
Engineers ran the first test May 20 of the parachutes that will float the Ares I rocket's spent first stage to the ground for reuse. Ares I will loft astronauts to space after shuttle retirement.

FIRM EVIDENCE
Scientists reported May 22 in *Science* that sandstone layers up to 33 feet (10 meters) thick, imaged in Mars' Victoria Crater by the rover Opportunity, were once windblown sand dunes.

SHARPSHOOTER
The European Southern Observatory announced a new instrument May 30 — the X-shooter — that can record the entire light spectrum of a celestial object in one shot.

CURIOUS NAME
Twelve-year-old Clara Ma from Lenexa, Kansas, won the contest to rename NASA's Mars Science Laboratory, set to launch in 2011. The rover will be called Curiosity, NASA announced May 27.

JUNK SCIENCE
The European Space Agency (ESA) will begin tracking potentially hazardous space debris within a few years, ESA official Nicolas Bobrinsky said April 2.

YOU FIRST
On May 20, space station astronauts took the first sip of water made from recycled urine. The Station's new Water Recovery System cost $250 million.

MERCURY'S MAGNESIUM
Scientists with NASA's MESSENGER mission reported April 30 in *Science* that Mercury's surface rocks contain abundant magnesium, a possible clue to the planet's history.

Astronomers find a hidden supernova

When our closest supernova of the past 5 years exploded in galaxy M82 in 2008, no one saw it. But a team of radio astronomers recently discovered the supernova that its host galaxy's dust hides in all other wavelengths. The team published its findings in the May *Astronomy & Astrophysics Letters*.

The starburst galaxy M82, just 12 million light-years away, harbors extreme star formation and dust in its inner region. When the supernova SN 2008iz exploded within this dense environment, visible light was quickly absorbed in the dust and never made it to Earth's telescopes.

When the astronomers examined radio data from April 8, 2009, they found a ringlike structure reminiscent of a supernova remnant. After searching through data from March and May of 2008, they saw a radio source in M82 that outshines the entire galaxy. "Our current data indicate that the star exploded in late January or early February 2008," says Andreas Brunthaler, lead author of the study. — **L. K.**

Radio rules. The galaxy M82 has so much dust that it blocked a new supernova from view in all light except radio. NASA/ESA/The Hubble Heritage Team (STScI/AURA)

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25 years ago in *Astronomy*

September 1984

In the September 1984 issue of *Astronomy*, David Darling wrote about high-energy radiation. In "Spectral visions, part 2: The short wavelengths and beyond," Darling discussed the electromagnetic spectrum and its high-energy region. (Part 1, the low energies, appeared in August 1984.)

These high energies (and therefore short wavelengths) include radiation such as ultraviolet, X-ray, and gamma-ray. Many of today's space-based observatories — Fermi, Chandra, and XMM-Newton — focus on these high energies.

Astronomers use high-energy radiation in combination with lower energies to study odd objects, such as supernovae and active galaxies, and more common objects, like our Sun and neighboring planets. "This has given us a more balanced perspective and a deeper understanding of the universe," wrote Darling.

September 1999

10 years ago in *Astronomy*

In the September 1999 issue of *Astronomy*, current Contributing Editor Bob Berman provided a helpful pronunciation guide written in his humorous style. Berman covered all constellations and the 21 brightest stars in "The art of skyspeak."

This pronunciation guide will help anyone who's ever wondered whether it's "VAY-gah" or "VEE-gah" (it's actually the latter). Plus it's a good source to bring along to the next star party to ensure you don't embarrass yourself.

To round out the guide, Berman (pronounced BURR-man) also included a brief discussion of pronouncing comets and meteor showers. — **L. K.**

Stellar web site

NASA's Cassini mission web site, http://saturn.jpl.nasa.gov, won a Webby award for best science site, the space agency announced May 6. The International Academy of Digital Arts and Sciences sponsors the annual award.

New method found to chart cosmic distances

Cosmologists rely on a kind of exploding star called a type Ia supernova to gauge cosmic distances. Now it seems they have a new method to measure the supernova's brightness, and therefore distance, more accurately and quickly. This new method will appear in an upcoming issue of *Astronomy & Astrophysics*.

Members of the consortium called the Nearby Supernova Factory studied the light signatures, or spectra, of 58 type Ia supernovae. They found that the ratio between the brightnesses of two specific colors in the spectrum correlates to the supernova's brightness. Because type Ia supernovae have fairly consistent luminosities, astronomers can determine a supernova's distance from its measured brightness. The specific colors astronomers compared are red-orange (642 nanometers) and purple-blue (443nm).

The traditional method to measure a type Ia supernova's distance is to study the time it takes for the exploding star to reach maximum brightness and then fade away. That can take a few months and gives an uncertainty of 8 to 10 percent. This new method needs data from only one night's measurement and gives an uncertainty within 6 percent. — **L. K.**

NASA/JPL-Caltech/W. Reach (SSC/Caltech)

Elephant's trunk. This section of the emission region IC 1396 in Cepheus goes by the name "Elephant's Trunk Nebula." This 2003 photo was one of the first taken by the Spitzer Space Telescope, which ran out of liquid-helium coolant May 15.

Spitzer warms up

On May 15, NASA's Spitzer Space Telescope ran out of liquid helium, the coolant needed to keep some of the infrared telescope's instruments at operating temperatures. Despite the loss of coolant, Spitzer will continue with what NASA calls a "warm" mission.

The liquid helium had lasted more than 5.5 years — twice as long as mission planners originally projected. It kept Spitzer's instruments at a bone-chilling –456° Fahrenheit (–271° Celsius). Now, the telescope has warmed all the way to –404° F (–242° C).

Although two of the telescope's instruments no longer work, two short-wavelength detectors still function perfectly. Spitzer will continue to peer through the dust that permeates our galaxy and view dust-shrouded stars, planet-forming disks, gas giant planets, and distant galaxies.

"We will do exciting and important science with these two infrared channels," says Spitzer Project Scientist Michael Werner of NASA's Jet Propulsion Laboratory. "Our new science program takes advantage of what these channels do best." — **R. T.**

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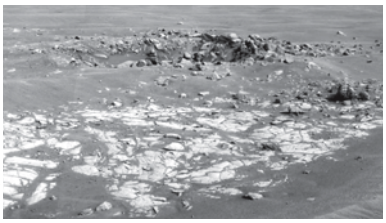
NASA's 2010 budget On May 7, NASA announced an $18.69 billion budget for fiscal year 2010. This represents a 5 percent increase over the previous year.



NASA/JPL-Caltech

Youthful impact. Fresh rocks surround Resolution Crater, seen in this image's background. Scientists say this crater formed no more than 100,000 years ago.

Mars rover spies young crater

Most of the impact craters in the solar system formed billions of years ago. And most younger examples still have ages measured in millions of years. So, imagine scientists' surprise when the Mars rover Opportunity rolled up to a small crater created within the past 100,000 years.

Scientists named the feature Resolution Crater. It's by far the youngest crater yet seen by either of the twin rovers. (Orbiting spacecraft have detected martian craters formed within the past few years, although the view from orbit precludes a close-up look.) NASA released the baby pictures April 29.

Signs of Resolution's youth include fresh rocks on the crater's rim and a bowl devoid of windblown sand. As a crater ages, martian winds sandblast exposed surfaces, softening its appearance. Scientists will compare Resolution with older craters to learn how fast the wind erodes the surface. — **R. T.**

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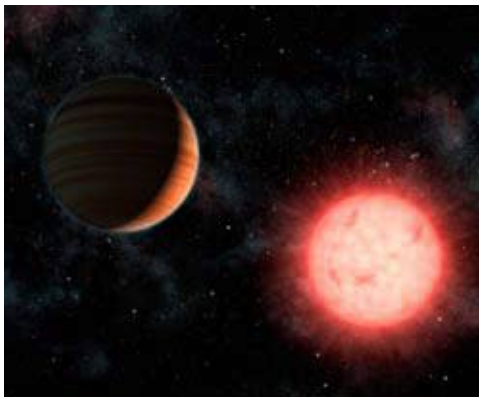

NASA/JPL-Caltech

Do-si-do. An old exoplanet-hunting method nabbed a new world, VB 10b. This "cold Jupiter" orbits a star similar in diameter to the planet.

Planet-hunting method snags its first

It took some 50 years, but a type of planet-hunting method called "astrometry" has nabbed its first exoplanet. In astrometry, astronomers look for changes in a star's position across the sky caused by an unseen planet tugging on the star. Two astronomers from NASA's Jet Propulsion Laboratory in Pasadena, California, have discovered a planet using this method. Their finding will appear in an upcoming issue of *The Astrophysical Journal*.

To find the newly discovered planet VB 10b, Steven Pravdo and Stuart Shaklan attached an instrument for precisely measuring star positions to the 5-meter Hale Telescope at Palomar Observatory a few times a year during the past 12 years. Out of the 30 stars they observed, one showed slight movement in its position that could be attributed to a planet.

VB 10b is some 6 times Jupiter's mass and orbits its star at roughly Mercury's distance from the Sun. Even at this close distance, VB 10b is considered a "cold Jupiter" because its star, VB 10, is only one-twelfth the Sun's mass. Therefore, the star doesn't radiate enough energy to heat the planet to high temperatures. Following this discovery, VB 10 is the smallest star known to host a planet. — **L. K.**

Herschel and Planck on their way

On the afternoon of May 14, the European Space Agency (ESA) launched two spacecraft on an Ariane 5 ECA rocket from Kourou, French Guiana. Planck will study the cosmic microwave background (CMB), the relic radiation left over from the universe's birth in the Big Bang. Herschel will explore the infrared cosmos using a 3.5-meter mirror, the largest ever lofted into space.

Launching both spacecraft on a single rocket posed challenges for ESA, but ones the space agency was willing to risk to save money. (Total mission cost: $2.5 billion [1.8 billion euros].) Still, the launch and subsequent separation went off without a hitch.

Some 26 minutes after launch, and within 2 minutes of each other, the rocket's upper stage released Herschel and Planck on separate trajectories that will take them to their final orbits around Sun-Earth L2. This point of gravitational balance lies some 900,000 miles (1.5 million kilometers) from Earth in the direction directly opposite the Sun.

L2 offers an environment relatively free of heat and radiation interference from the Sun, Earth, or the Moon. Still, for the precise observations they must make, both will be cryogenically cooled to temperatures near absolute zero. It will take the spacecraft approximately 2 months to reach their final orbits. Once there, they will begin observing the sky, although routine operations likely won't begin for another month or two.

Planck will map tiny irregularities in the structure of the CMB radiation. It will have better than 10 times the sensitivity and 3 times the angular resolution of NASA's still-functioning Wilkinson Microwave Anisotropy Probe (WMAP). Scientists expect Planck to measure temperature differences in the CMB as small as one-millionth of a degree.

The CMB, released when the universe became transparent to radiation some 380,000 years after the Big Bang, holds clues to fundamental parameters governing the origin and evolution of the cosmos, including how large-scale structure arose. Planck scientists also expect the mission to shed new light on the mysterious dark matter and dark energy.

ESA/S. Corvaja

A twofer. **An Ariane 5 ECA rocket blasts off from French Guiana carrying the European Space Agency's Herschel and Planck spacecraft on their way to Sun-Earth L2.**

Herschel will observe at far-infrared and submillimeter wavelengths, a region of the electromagnetic spectrum that astronomers have yet to explore in detail. Herschel's prime mission is to study the birth of stars and galaxies and the relationship between the two. It can do so because the long-wavelength radiation it detects passes easily through the dust clouds that block our view at visible wavelengths.

The observatory will also give scientists good views of interstellar clouds of gas and dust, the planet-forming disks surrounding newborn stars, and the atmospheres of the solar system's gas giant planets and comets. In addition, Herschel will be the best tool yet for detecting water vapor in remote parts of the universe.

Planck will complete two sky surveys in its first 15 months. It likely will continue observing the CMB for another year, depending on how much coolant remains. Herschel has enough coolant to last at least 3 years. — **R. T.**

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The day Earth

At some point in the dim past, non-living matter started to replicate itself. Scientists are still trying to figure out how. **by James Trefil and Wanda O'Brien-Trefil**

Cosmologists know the universe began with the Big Bang approximately 13.7 billion years ago. Astronomers know Earth formed from material in a debris disk surrounding the fledgling Sun. And planetary scientists know with nearly the same certainty that the Moon arose in the aftermath of a massive collision between a Mars-sized object and Earth early in solar system history.

It seems that scientists have a good handle on how everything around us began, with one glaring exception: We don't know where life came from. The question of how living things arose from non-living matter is still wide open, fueling one of science's most exciting fields.

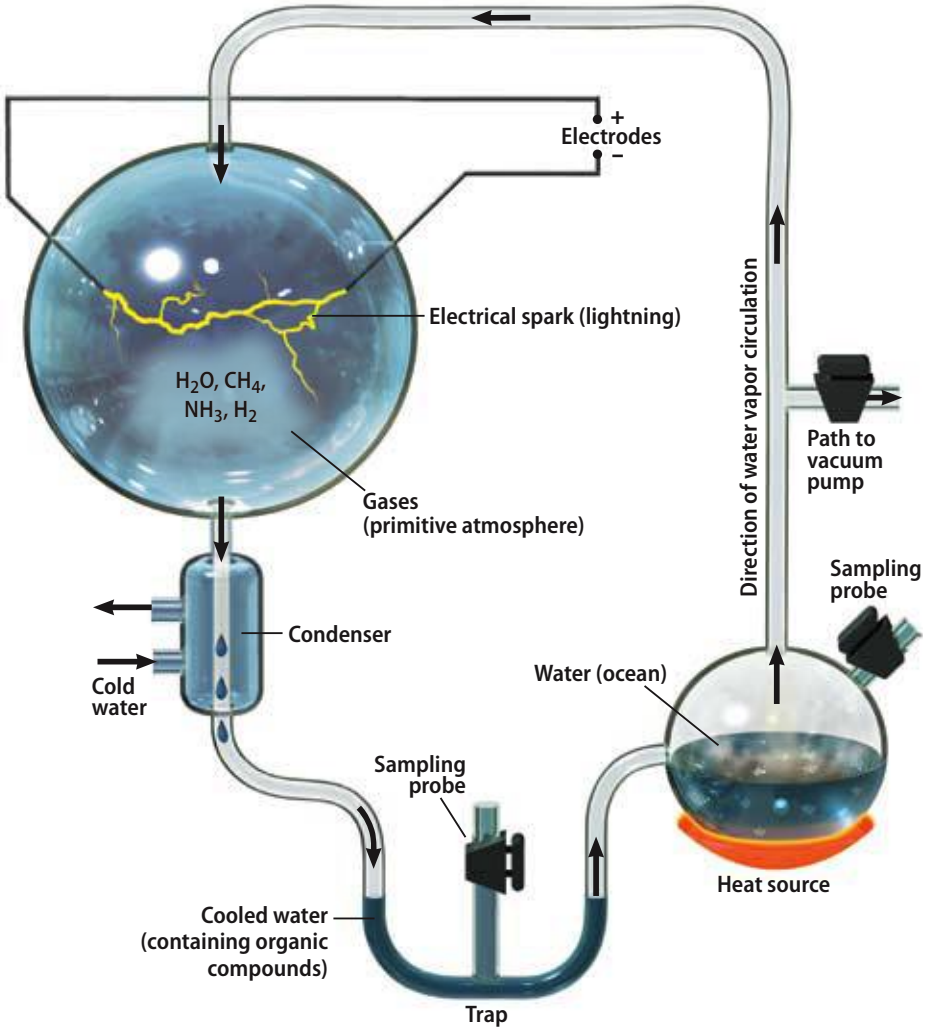
In the 19th century, scientists like Louis Pasteur and Rudolph Virchow led an intellectual revolution by proving that life is not spontaneously generated. Their mantra became: "Life comes from life."

James Trefil *is the Clarence J. Robinson professor of physics at George Mason University in Fairfax, Virginia. He works with the origin-of-life researchers at the Santa Fe Institute.*
Wanda O'Brien-Trefil *teaches English in the Montgomery County, Maryland, public schools.*

came to **life**

A warm tidal pool may have been the genesis for life on Earth. A rich brew of organic molecules, brought in by comets and meteors or created through lightning strikes, somehow found a path toward a self-replicating system. Ron Miller for *Astronomy*

The Miller-Urey experiment



The Miller-Urey experiment in 1953 started with a mix of water (H_2O), methane (CH_4), ammonia (NH_3), and hydrogen (H_2). The researchers then heated the water to simulate the Sun and ran electrical sparks through the resulting vapor to simulate lightning. They wound up with lots of organic compounds, including amino acids — basic building blocks of life. *Astronomy*: Roen Kelly

Although philosophers can get into enormous nitpicking arguments about the precise definition of "life," the fact remains that when we say something is alive, we mean it is running certain types of chemical reactions. In the words of biologist Harold Morowitz of George Mason University and the Santa Fe Institute, "Life is like pornography — I may not be able to define it, but I know it when I see it."

The stuff of life

The idea that life always comes from pre-existing life served scientists well for more than a century. They worked out the theories of evolution and molecular biology but typically pushed the origin question to the back burner. The problem never went away, however. There had to be a time when life didn't come from life, but from non-living matter. The science of the late 19th and early 20th centuries simply wasn't equipped to deal with this fact, so scientists largely ignored the question.

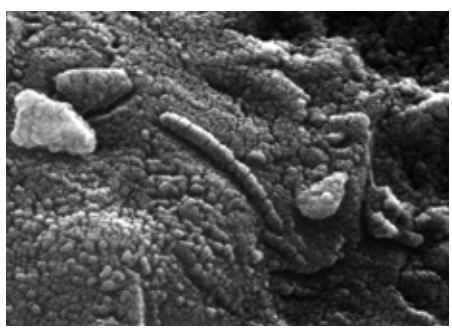
This situation changed in 1953, in the basement of the chemistry department at the University of Chicago. Harold Urey, who was already a Nobel laureate, and his graduate student Stanley Miller ran an experiment that forever changed the way scientists thought about the origin of life. In a sealed glass bulb, Urey and Miller put materials they thought would have been present on the early Earth: water, hydrogen, ammonia, and methane.

The researchers then heated the water to simulate the action of the Sun and ran electrical sparks through the resulting vapor to simulate the effects of lightning. And then they waited. After a few days, the liquid in the bulb began to turn a murky brownish red. Urey and Miller analyzed the liquid and found that it contained amino acids, one of the basic building blocks of life's chemistry.

This experiment had a profound effect on the study of life's origin. For the first time, it showed that perfectly natural processes can produce the kinds of molecules found in living systems. In the years that followed, people such as the late Cyril Ponnamperuma of the University of Maryland showed that experiments similar to Miller and Urey's could produce all sorts of other molecules associated with life.

Most scientists today don't think the exact process explored by Miller and Urey happened on the early Earth because they didn't get the initial mix of chemicals right. That doesn't really matter. In the half century since the Miller-Urey experiment, researchers have found amino acids and other organic compounds in meteorites, comets, and even interstellar dust clouds. In other words, it's not hard to find the stuff from which life is made. The problem is to explain how that stuff assembled into the first living thing.

Unfortunately, scientists don't even know what that early life looked like. The life we see around us is enormously complex. It is much harder, for example, to sort out what's happening in a single cell in your body than it is to track the nuclear reactions in an exploding supernova. The issue is whether something like modern complexity was there at the beginning of life or whether that complexity evolved from simpler beginnings.



Martian meteorite ALH84001 and this embedded wormlike structure ignited debate about life on Mars. Although most scientists now suspect these structures are not microscopic fossils, ALH84001 convinced NASA to make the search for life a top priority. NASA

^ Brilliant meteors, called fireballs, sometimes survive their passage through Earth's atmosphere to become meteorites. Scientists have found amino acids in some meteorites. Bristen Bourque

> Organic-rich meteorites may have delivered the seeds for life to Earth during our planet's first few hundred million years. This meteorite fell in Sudan in October 2008. NASA

Bill and Sally Fletcher

Comets like Hale-Bopp may have brought water and organic molecules to the early Earth, helping to seed it with the materials necessary for life.

A warm little pond

For several decades after the Miller-Urey experiment, scientists leaned toward a view with the appealing name "Primordial Soup." The idea was that the concentration of organic molecules in Earth's early ocean gradually built up through the action of lightning or the influx of meteorites and comets. These molecules likely became concentrated further in places like tidal pools. (Charles Darwin had presciently referred to this location for life's origin as a "warm little pond.")

Then, the argument went, a chance assembly of molecules somewhere had just the right properties to allow it to take in energy and reproduce itself — life had begun. Given enough time and a high enough concentration of organic molecules, such a chance occurrence was virtually inevitable. Some scientists put forward other ideas, among them that life formed on clay soils or near volcanoes.

Progress in origin-of-life studies remained slow, however, for two main reasons. First, during the 1970s and 1980s, biologists were just beginning to work out the full details of life's complex chemistry. And second, only a few laboratories in the world were working on this problem. Few people felt that the field had advanced to the stage where a major influx of money would produce important results.

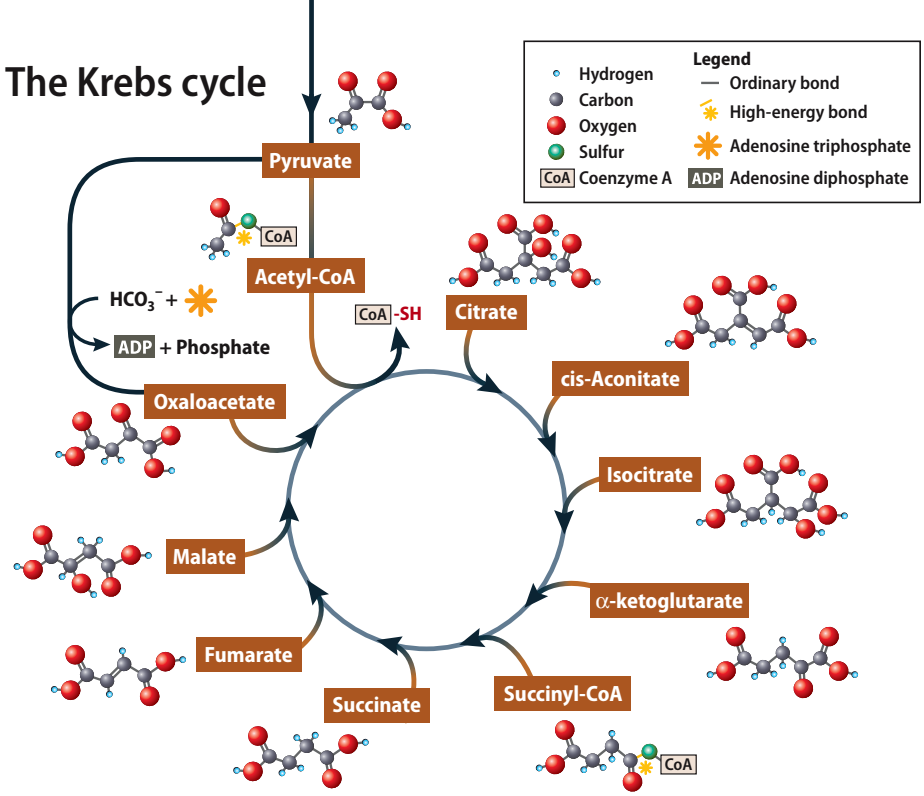
All that started to change with the 1984 discovery of a unique meteorite in Antarctica's Allan Hills ice field named ALH84001. An analysis of gases trapped inside the meteorite showed that it came from Mars. But the key breakthrough came in the mid-1990s when NASA scientist David McKay and his colleagues claimed that the meteorite contained microscopic fossils. (A majority of scientists now think the intriguing structures are mineral formations and not fossils.)

The possibility of life on Mars ignited so much excitement that NASA decided to make the search for life elsewhere a part of its mission. And if you're going to talk about finding evidence for life elsewhere in the universe, it makes sense to understand the origin of the only life we know about for sure — life on our own planet. So, the 1990s saw the first major, well-funded research efforts into the origin of life on Earth.

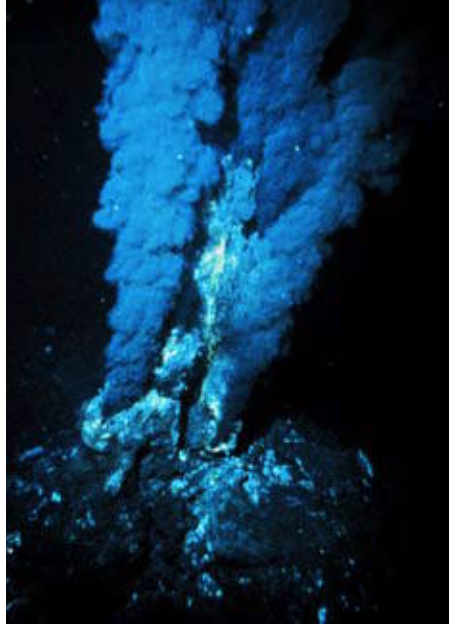
This means that now, for the first time since 1953, scientists are engaged in a rich froth of debate about the origin of life. They propose new ideas, and experiments provide both a guide and a check on the theories. This is the way science is supposed to work.

The law of the land

Current theories about life's origin lie on a continuum between "accidental" theories and "lawful" theories. The classical version of the Primordial Soup is a good example of an accidental theory. The molecules swirl around at random, and their coming together into the first primitive cell represents an accidental, unrepeatable event.

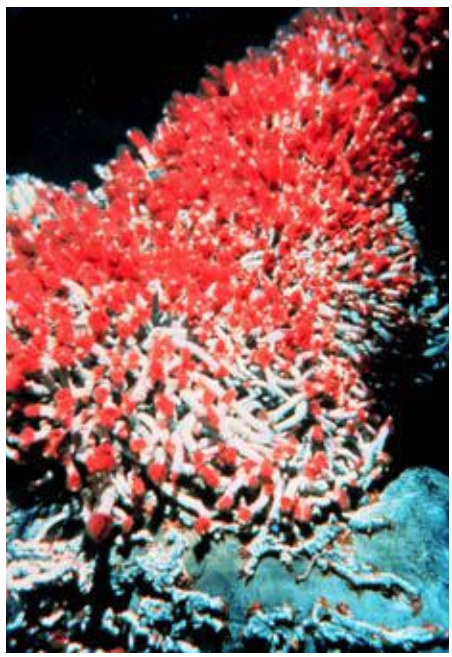


The Krebs cycle is a complex series of chemical reactions in the cells of living creatures in the higher animal kingdom (including humans) that breaks down large molecules in food to produce energy in the form of the molecule adenosine triphosphate (ATP). *Astronomy:* Kellie Jaeger



OAR/National Undersea Research Program/NOAA

A "black smoker" belches from a hydrothermal vent on the Atlantic Ocean's mid-ocean ridge. Some scientists think the first life on Earth may have developed near such deep-sea vents.



OAR/National Undersea Research Program/NOAA

Tube worms feed at the base of a hydrothermal vent. Ancient ancestors of such life forms may have been Earth's first self-reproducing molecules, isolated from their environment inside minuscule rock pores.

A lawful version of the Primordial Soup scenario, on the other hand, would be one governed by a set of laws. These laws, either known or knowable, would drive some reaction pathways in preference to others and produce a predictable outcome.

Think of the difference this way: We all know that it is possible to mine gold and produce gold jewelry. An accidental theory would hold that finding many atoms of gold together on Earth's surface is an unpredictable process produced by the random mixing of materials.

A lawful theory, on the other hand, would cite the known laws of chemistry to explain why gold atoms tend to clump together. In this theory, which experiments verify, the basic laws of nature predict the existence of gold nuggets. In the same way, proponents of lawful theories would argue that life itself is a predictable outcome of natural laws, although most would agree that we have not yet discovered those laws.

Many scientists champion a hybrid of accidental and lawful theories of life's origins called "RNA World." In modern cells, the molecule RNA (ribonucleic acid) plays a major role in translating the genetic code carried in DNA (deoxyribonucleic acid) into the enzymes that govern chemical reactions. In the 1980s, however, biologists discovered that some kinds of RNA can act as enzymes themselves. In many versions of RNA World, the first RNA molecules came together by chance, but they then acted as enzymes and ran reactions according to the ordinary laws of chemistry.

From particular to general

Theories on the origin of life also break down into "particular" theories and "general" theories. Darwin's warm little pond falls into the particular category. Such a pond can exist only on a planet that has particular conditions, such as a moon (or moons) capable of raising tides. The basic idea holds that tidal fluctuations keep dumping new "soup" into the pond, and evaporation concentrates it. This type of theory is particular because, if it is true, life will occur only on planets that have liquid water on their surfaces and at least one large moon.

Michael Russell of NASA's Jet Propulsion Laboratory proposes a completely different particular theory. He suggests that the first assembly of self-reproducing molecules occurred inside tiny pores in rock located near certain deep-sea vents. This theory has the advantage of not requiring the first cell to have a membrane to separate it from its environment. Membranes would be needed only when life left the rocks.

If this theory is correct, however, life could develop only on planets that have plate tectonics and hence deep-sea vents. All particular theories would restrict the presence of life in the universe.

A general theory, on the other hand, would be one in which life could be expected to arise in a wide variety of environments. The best current example

of this kind of theory goes by the name "Metabolism First," developed in a major research collaboration centered at the Santa Fe Institute in New Mexico. It begins with an examination of the complex way that chemical reactions work in living systems today.

At the core of every living system is something called the Krebs cycle, which involves only 11 basic molecules. In your body, this cycle generates energy by breaking down the large molecules from your food. In some primitive single-celled organisms, however, it operates in reverse — it takes in energy and puts small molecules together into big ones. Scientists term the reactions in this mode as the "reductive Krebs cycle."

On the road to complexity

The basic premise of the Metabolism First approach is that this simple reductive Krebs cycle characterized the first things we could call living. That first cell wouldn't have looked anything like a modern cell, of course.

In this picture, all the complexity of modern systems — DNA, RNA, genes, and the rest — came later through a slow evolutionary process governed by the laws of natural selection.

The current U.S. interstate highway system makes a good analogy. This enormously complex system not only requires road builders, but also car manufacturers, petroleum refineries, delivery systems, and more. Yet if we could look at North America 600 years ago, we would find only a network of game trails and footpaths. Over the centuries, those game trails evolved into wagon trails, then into narrow paved roads, and only then into the present system. This is a system that started simple and evolved into something complex. The argument is that the complexity in today's living systems evolved in much the same way from a simple beginning.

But even if future research shows that complexity developed this way, we're left with the question of why these particular chemical reactions showed up in the first place. The best way to approach this question is to ask it in the provocative way first posed by Eric Smith of the Santa Fe Institute: "What problem was there in the early Earth that was solved by the development of life?"

USGS/CVO

Volcanoes could have played a role in life's emergence. (Here, Mount St. Helens erupts in July 1980.) Some experiments show such eruptions spew gases that can aid the chemical reactions necessary for life.

Smith likens the problem to a thunderstorm. Consider a thundercloud passing over a tree. Air currents in the cloud allow heavy, negatively charged particles to collect near the bottom of the cloud while lighter, positively charged particles waft to the top. The negatively charged particles, being close to the tree, push electrons in the tree away, and the tree acquires a positive charge.

The "problem" in this situation is that the negative charges in the cloud want to combine with the positive charges in the tree. So, nature creates a channel in the air through which the charges flow, solving the problem with a bolt of lightning.

In just the same way, Smith argues, ordinary geological processes on the early Earth push electrons into high-energy states. The "problem" is that these electrons, like the negative charges in the thundercloud, want to get down to lower energies. One way for them to do this is to use the chemical reactions characteristic of living systems. In effect, these reactions create a "lightning bolt" in the chemical landscape. In this scheme, the appearance of living systems on a planet is no more mysterious than the appearance of lightning in the sky.

The beauty of this theory is that it tells us life can arise anywhere in the cosmos where normal geological processes can be found. In fact, if the Metabolism First theories are borne out, we will be able to say that the universe not only allows life to exist, but requires it.

Would exolife have the same chemistry? Find out at www.Astronomy.com/toc.

What revved up the galaxy's hyperfast stars?

Since 2003 astronomers have found 16 stars escaping the Milky Way's gravity. The slingshot could be our galaxy's central black hole. **By Ray Jayawardhana**

A handful of stars are speeding through the Milky Way, and appear to be on their way out. Our galaxy's gravity can't hold onto them because they're traveling so fast. Astronomers first discovered these hypervelocity objects just 6 years ago. Decades before, however, some theorized the stars existed and even put forth theories for their speeds.

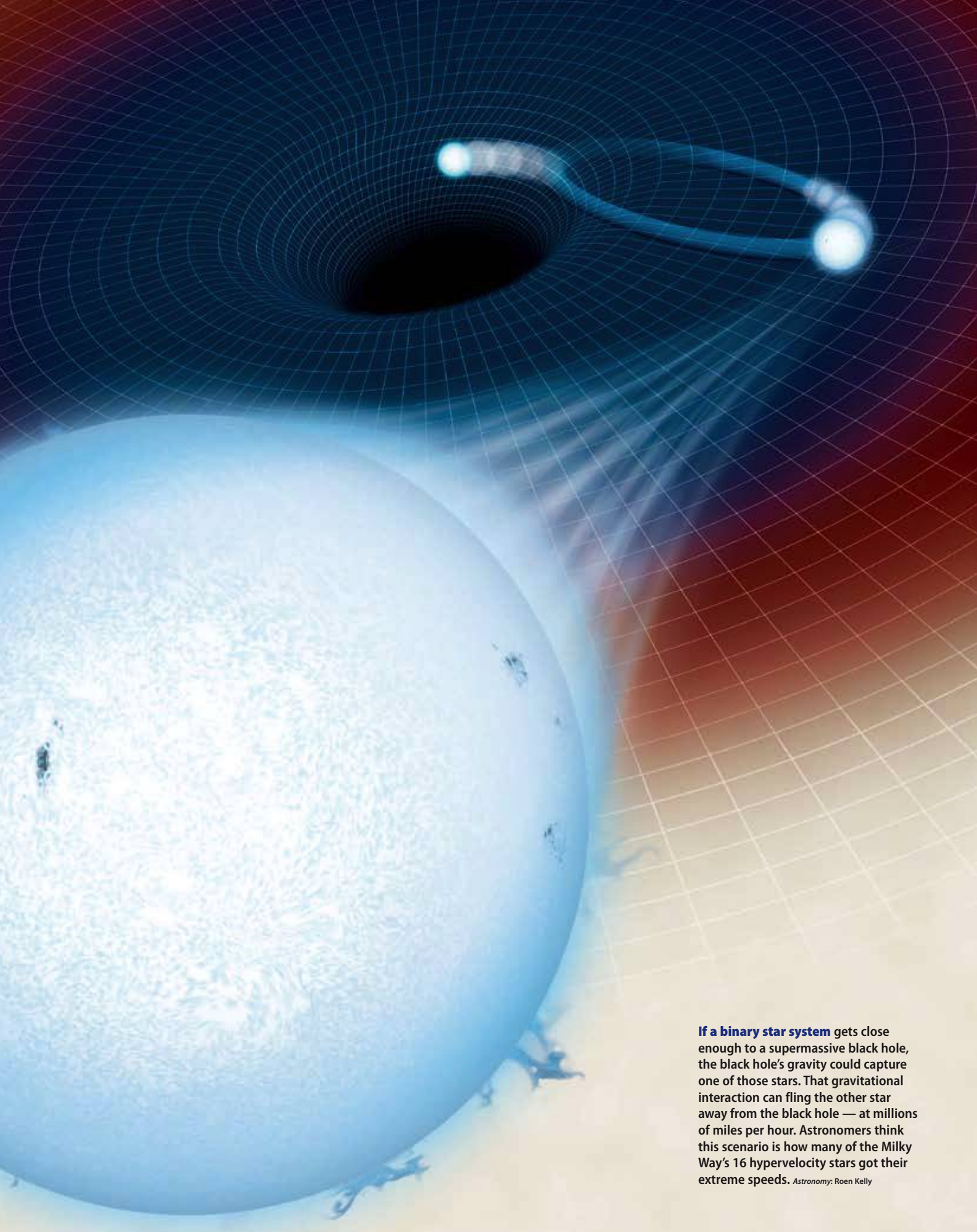
If a tight stellar binary swings too close to a massive black hole, one star can end up circling the monster while the other is flung out at millions of miles per hour. Jack Hills, a theorist at the Los Alamos National Laboratory in Los Alamos, New Mexico, predicted this dramatic scenario in a 1988 paper published in the journal *Nature*. "The discovery of even one such hypervelocity star coming from the galactic center would be nearly definitive evidence for a massive black hole," he wrote.

For 15 years, astronomers didn't pay much attention to Hills' scenario. Meanwhile, compelling evidence has accumulated for a black hole some 3.7 million times the Sun's mass at the heart of the Milky Way. Two groups carefully measured the motions of a handful of stars orbiting nearest to the black hole.

In 2003, Qingjuan Yu, then at the Canadian Institute for Theoretical Astrophysics, and Scott Tremaine of Princeton University wrote a paper that expanded on Hills' work. They estimated ejection rates and suggested that future wide-field imaging surveys could detect hypervelocity stars fairly easily by measuring their motions across the sky.

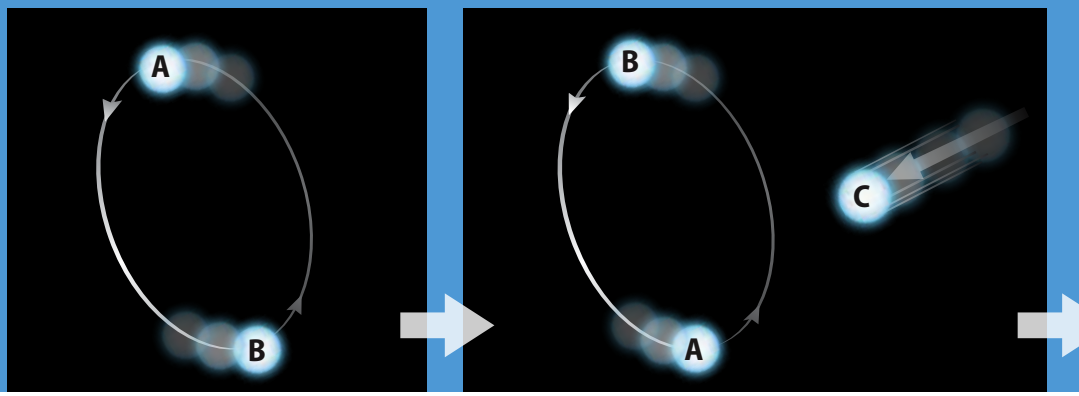
Too blue, too fast

Warren Brown, a staff astronomer at the Harvard-Smithsonian Center for Astrophysics (CfA), hadn't heard of hyperfast



If a binary star system gets close enough to a supermassive black hole, the black hole's gravity could capture one of those stars. That gravitational interaction can fling the other star away from the black hole — at millions of miles per hour. Astronomers think this scenario is how many of the Milky Way's 16 hypervelocity stars got their extreme speeds. *Astronomy*: Roen Kelly

Stellar dance



Stellar interactions within a dense star cluster can accelerate stars. Some researchers think this type of interaction may have flung HE 0437–5439 out of the Large Magellanic Cloud. *Astronomy*: Roen Kelly based on simulations by Alison Sills

stars prior to a 2003 observing session using the 6.5-meter Multiple Mirror Telescope (MMT) atop Mount Hopkins, Arizona. His plan was to record the spectra — light spread into its constituent wavelengths — of faint blue stars far from the galactic disk. He expected these objects would be evolved low-mass stars that burn helium in their cores after exhausting their hydrogen supplies. Older stars such as these would help Brown trace the mass distribution in the galaxy's outer halo. And some of them might belong to "stellar streams" — the tidal debris of satellite galaxies cannibalized by the Milky Way long ago — which would be an interesting find in its own right.

When the astronomer analyzed the spectra months later, the bluest star in his sample, tagged SDSS J090745.0+024507 based on its sky coordinates, caught Brown's attention. It was also the fastest. "What an outlier!" he thought.

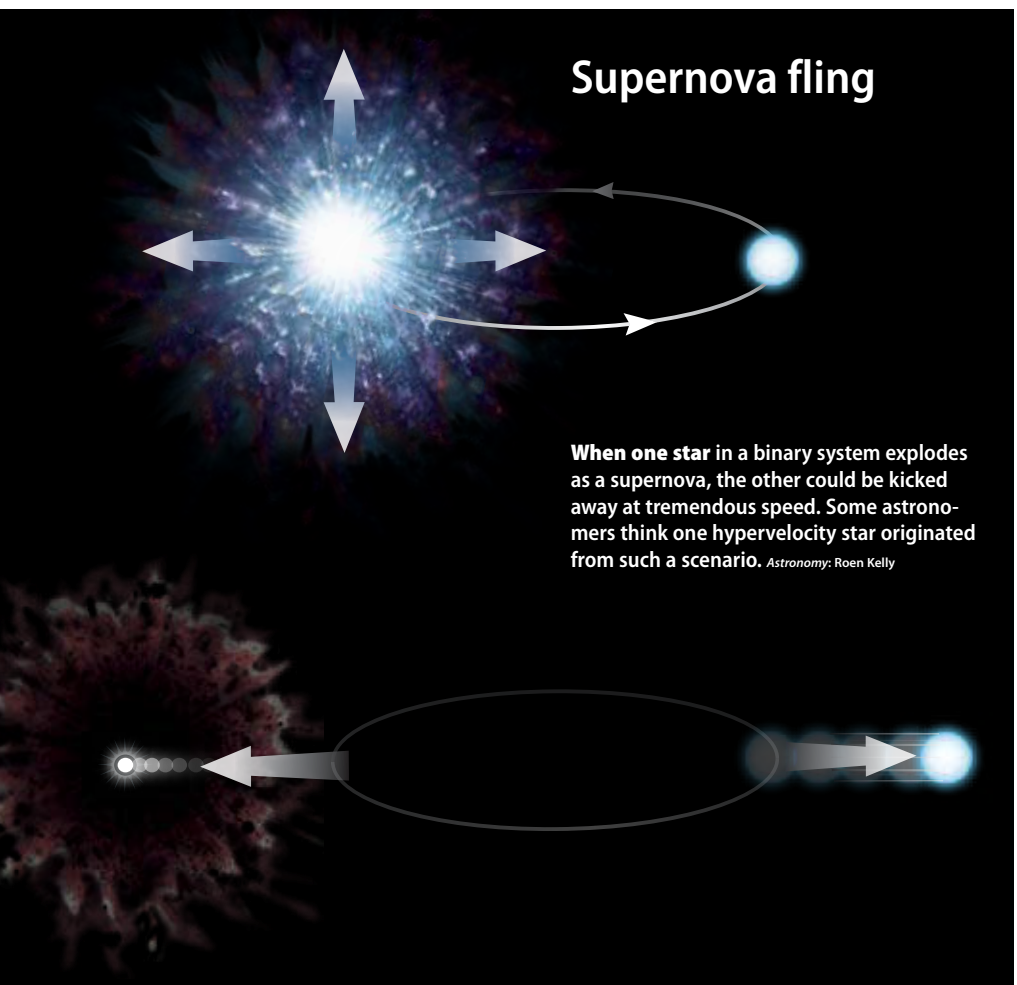
Traveling at 1.56 million mph (2.51 million km/h), it seemed too fast to be the type of star Brown was looking for, or even a runaway kicked out of a binary system. What's more, at that speed it would escape from the Milky Way Galaxy's gravitational clutches altogether. Brown searched the scientific literature for clues and came across the papers by Hill and by Yu and Tremaine. He became convinced that "only the powerful gravity of a very massive black hole could have propelled it."

Moreover, the star's line-of-sight velocity — its speed directly toward or away from Earth — suggests that it is moving almost directly away from the Milky Way's core. The star's composition and age also appear consistent with such an origin. It's rich in heavy elements (called "metals"), which hints at a birthplace like the star-forming region near the galactic center, and it's only about 80 million years old — just enough time for it to have reached its current location.

Brown reported his serendipitous discovery of the first hypervelocity star in early 2005. Shortly thereafter, he and his CfA colleagues Margaret Geller and Scott Kenyon set out to do a targeted search for others like it. Theorists estimate that only about 1,000 of the galaxy's more than 100 billion stars are these outcasts. To improve their odds searching for the proverbial "needles in a haystack," the team looked for faint blue stars in the Sloan Digital Sky Survey (SDSS). Such objects are likely distant, somewhat young, and with a higher mass. The astronomers were careful to leave out candidates that are so blue that they might be stellar cinders known as white dwarfs. Unfortunately, their first dedicated observing run, in the summer of 2005, was canceled when smoke from a nearby forest fire engulfed the Mount Hopkins summit.

Meanwhile, a group of European astronomers led by Ulrich Heber of the University of Erlangen-Nürnberg in Germany reported two more hypervelocity

Supernova fling



When one star in a binary system explodes as a supernova, the other could be kicked away at tremendous speed. Some astronomers think one hypervelocity star originated from such a scenario. *Astronomy*: Roen Kelly

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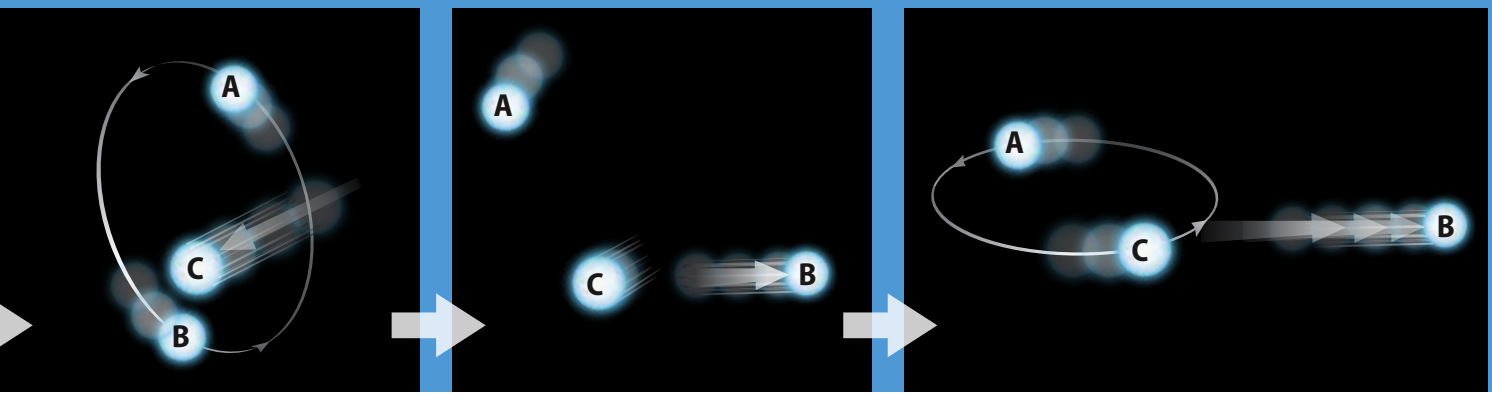
Contributing Editor **Ray Jayawardhana** *holds the Canada Research Chair in Observational Astrophysics at the University of Toronto. Caldwell Parners recently named him as one of Canada's Top 40 Under 40.*



Stellar speedsters

ID	Distance to galactic center (thousands of light-years)	Velocity* (million mph [million km/h])	Catalog name
HVS† 1	362	1.56 [2.51]	SDSS J090744.99+024506.9
HVS 2	85	1.60 [2.58]	US 708
HVS 3	202	1.23 [1.97]	HE 0437-5439
HVS 4	268	1.33 [2.04]	SDSS J091301.01+305119.8
HVS 5	147	1.45 [2.34]	SDSS J091759.48+672238.3
HVS 6	255	1.18 [1.90]	SDSS J110557.45+093439.5
HVS 7	196	0.93 [1.50]	SDSS J113312.12+010824.9
HVS 8	173	0.91 [1.47]	SDSS J094214.04+200322.1
HVS 9	222	1.09 [1.75]	SDSS J102137.08−005234.8
HVS 10	284	0.97 [1.56]	SDSS J120337.85+180250.4
HVS 11	228	0.75 [1.21]	SDSS J095906.48+000853.4
HVS 12	228	0.96 [1.54]	SDSS J105009.60+031550.7
HVS 13	408	0.99 [1.60]	SDSS J105248.31−000133.9
HVS 14	366	0.93 [1.50]	SDSS J104401.75+061139.0
HVS 15	277	0.77 [1.24]	SDSS J113341.09−012114.2
HVS 16	294	0.82 [1.32]	SDSS J122523.40+052233.8

Key: *Speed relative to the Milky Way's rest frame; †HVS=hypervelocity stars.
Content based on "MMT Hypervelocity Star Survey" by Warren Brown et al. (2008).

The Large Magellanic Cloud likely is the original home of hypervelocity star HE 0437–5439, not the Milky Way's center. For the star to get to its current location away from our galaxy's center, it would have had to have been traveling for a time span 3 times its age. Andreas B'ker and Axel Martin

stars, each somewhat more massive than the first, traveling away from us at about 1.6 million mph (2.5 million km/h). One star's location and characteristics pointed to a likely origin at the galactic nucleus. But the other posed a puzzle. "When we calculated how long it would take for the star to travel from the center of our galaxy to its present location, we found this to be more than 3 times its age," Heber says. Either the star had to be older than it appears, or it had to have been born elsewhere. Intriguingly, this star, dubbed HE0457–5439, lies close to one of the Milky Way's satellite galaxies, the Large Magellanic Cloud (LMC).

They came from the depths

Brown's team found two other hypervelocity stars during its observing run in December 2005. And over the next few years, they continued to discover more outcasts.

Now, the count has reached 16. As their cadres have increased, so have the peculiarities. For one, the evidence that HE 0437–5439 came from the LMC has become stronger. Recent analyses of high-resolution spectra by Heber's group, and independently by Alceste Bonanos, then of the Carnegie Institution of Washington, and her colleagues, show that the star's chemical abundance pattern closely mimics that of LMC stars rather than galactic center ones. Because the LMC is not known to harbor a massive black hole, some researchers suggest that other mechanisms may also toss out stars at extreme speeds. One such method is ejection through dynamical interactions in a dense star cluster.

But Brown, for one, isn't convinced. "It would have left the LMC at some 3.6 million km/h [2.2 million mph]. You just can't do that with stellar dynamics, so the LMC would have to harbor a black hole of perhaps tens of thousands of solar masses," he argues. There is no independent evidence that such a monster resides in the LMC.

HD 271791, another star traveling fast enough to escape from our galaxy, is also an odd beast. When astronomers trace its motion back, they find that it likely originated in the rim of the galactic disk rather than near the center. Moreover, a German research team including Heber found that the star's spectrum shows the star is poor in iron but it has an excess of elements produced during a supernova. Such a find agrees with the star being

Just plunging through

As a satellite galaxy plunges into the Milky Way, its stars would be strewn about. Those stars could reach breakneck speeds. Eight of the 16 known hypervelocity stars are clustered in the same direction around Leo, and some astronomers believe they could be from a satellite galaxy. The larger galaxy remains fixed in this illustration. *Astronomy*: Roen Kelly

Fastest yet

Despite their name, hypervelocity stars are not the fastest movers in the galaxy. The current confirmed record holder is a pulsar known as PSR B1508+55, clocked at almost 2.5 million mph (4 million km/h).

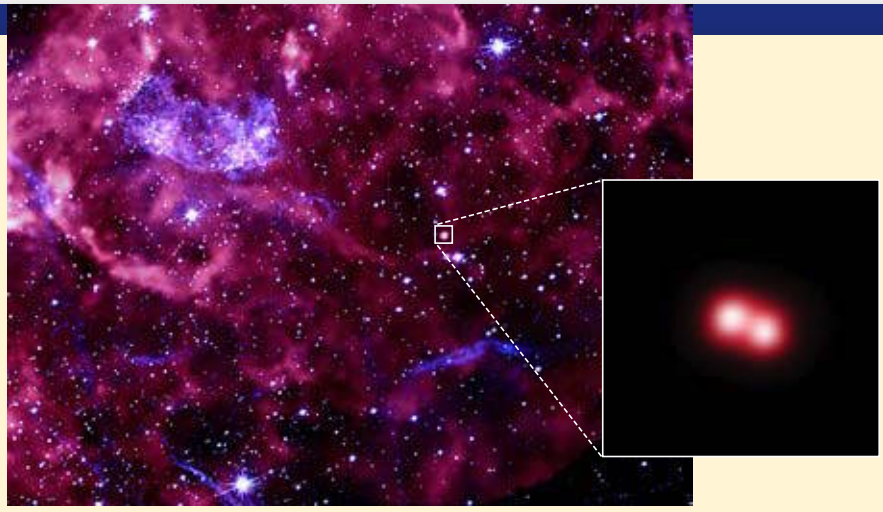
A pulsar is a rapidly rotating neutron star — the superdense collapsed core of a massive star that exploded as a supernova. Scientists observe radio "pulses" as beams of radiation from a pulsar's magnetic poles sweep past Earth. Three years ago, a team led by Shami Chatterjee, now at Cornell University in Ithaca, New York, precisely measured both the distance and the speed of PSR B1508+55 using an array of 10 radio telescopes spanning from the U.S. Virgin Islands to Hawaii. Plotting the pulsar's motion backward points to a birthplace among other massive stars toward the constellation Cygnus. That means PSR B1508+55 has traversed about one-third of the night sky as seen from Earth since the pulsar formed 2.5 million years ago.

Two other neutron stars also compete for the galactic speedster title. One, known as RX J0822–4300, is associated with the Puppis A supernova remnant. Observations spanning 5 years with NASA's Chandra X-ray Observatory show that it is rushing away from the center of the explosion, which occurred about 3,700 years ago. Its speed: between 2.5 and 3.7 million mph (4 and 6 million km/h), according to two research teams, assuming a distance of roughly 7,000 light-years. Unfortunately, that distance isn't confirmed.

The pulsar dubbed PSR B2224+65, whose bow shock and wake give rise to the spectacular Guitar Nebula, is the other contender. But because its distance also is uncertain, so is its speed. The best estimates put it between 1.8 and 3.6 million mph (2.9 and 5.8 million km/h). "So, the secure speed record belongs to PSR B1508+55, but the nicest picture award goes to the Guitar [Nebula]," says Marten van Kerkwijk, my colleague at the University of Toronto. He hopes to obtain a better distance estimate to the Guitar Nebula soon, so a clear winner in the speed-stakes may emerge in the near future.

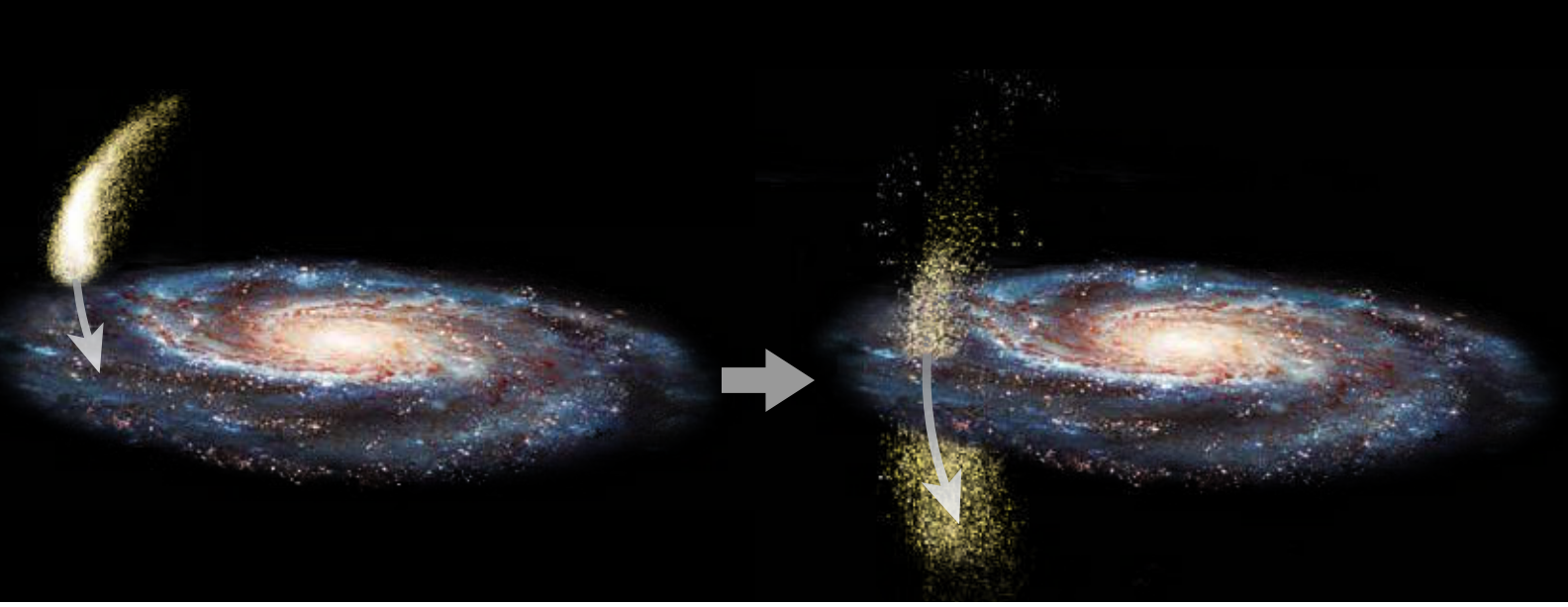
In the case of all three neutron stars, powerful jolts, or "kicks," during supernovae explosions are the most likely explanation for their extreme speeds. There is growing evidence that these explosions are lopsided, but the exact mechanism that causes the asymmetry remains a mystery. "It could involve hydrodynamics or possibly exotic physics in the presence of ultra-high magnetic fields," Chatterjee says. Astronomers find it difficult to produce sufficiently strong one-sided kicks in current computer simulations. "Not very surprisingly, the physics of supernova explosions has similarities to the physics of nuclear bomb explosions, so supercomputers work on both problems side by side," he explains.

Observers could also be missing many other fast-moving neutron stars. Most pulsar searches focus on the Milky Way's disk because that's where most pulsars are born and where they live. "After all, Willie Sutton robbed banks because 'that's where the money is,' " Chatterjee quips. But the fastest pulsars are the most likely ones to leave the galactic plane, taking them outside the search areas. "So we are very probably missing some of the highest-velocity pulsars in our surveys," he says. — *R. J.*



Some 3,700 years ago a supernova exploded to create the Puppis A supernova remnant. In that explosion, the stellar remnant neutron star was ejected and is now speeding through the nebula. Inset: The neutron star RX J0822–4300 has moved considerably between December 1999 and April 2005.

Chandra: NASA/CXC/Middlebury College/F. Winkler et al.; ROSAT: NASA/GSFC/S. Snowden et al.; Optical: NOAO/AURA/NSF/Middlebury College/F. Winkler et al.



born in the outskirts where there is a lower abundance of heavy elements. Their conclusion: HD 271791 is the surviving partner of a massive binary in which the other star exploded as a supernova, thus unbinding the system and letting the companion loose at a tremendous speed.

Where do they call home?

Two of the 16 fastest-moving stars found to date appear to have sped up without the aid of the galactic center black hole. Now three theorists — Mario Abadi of Córdoba Observatory in Argentina, Julio Navarro of the University of Victoria in Canada, and Matthias Steinmetz of the Astrophysical Institute of Potsdam in Germany — have raised new questions about other stars. They point out that if the Milky Way is about 3 times more massive than previously thought, as some galaxy-formation models suggest, only one of those designated as hypervelocity stars is traveling fast enough to escape from the galaxy's gravitational clutches.

That led them to consider alternative, more prosaic mechanisms for the origin of these stars. In particular, eight of the remaining 14 hypervelocity stars happen to lie in the direction of the constellation Leo. According to these theorists, the stars may come from elsewhere. Their computer simulations show that stars from a disrupted satellite galaxy plunging into the Milky Way could reach breakneck speeds. What's more, such stars would naturally form a long stream or tail, so the eight seen toward Leo would belong to a tail seen "end on." Based on the stars' locations and speeds, Abadi and colleagues estimate that this parent galaxy was torn apart between 100 and 200 million years ago.

Brown concedes that some hypervelocity stars could have an origin different from a massive black hole, like a cannibalized satellite galaxy. But he is skeptical such a mechanism could account for the majority. "The fastest half-dozen stars would almost certainly have to come from the galactic center supermassive black hole," he argues.

Future observations should distinguish between the two scenarios: Stars from dwarf galaxies would be poor in heavy elements, whereas those flung out from the galactic center should be metal-rich. Astronomers need high-resolution spectra to tell the difference. Therein lies the rub: Most of these stars are too faint for high-resolution spectroscopy with even the biggest telescopes currently available.

The stars' rotation speeds could also provide clues: Those ejected by Hills' mechanism would come from binaries where tides have slowed their rotations. Other scenarios can catapult rapidly rotating single stars. So far, the evidence is inconclusive. Brown and others are also trying to obtain the hypervelocity stars' motions in 3-D to determine more accurately where they're from. The astronomers aim to do this by combining measurements of the objects' movements across the sky (called "proper motions") with line-of-sight velocities from spectra.

Captured siblings?

Other clues could come from studies of stars circling closest to the galaxy's central black hole. Since the early 1990s, two teams of astronomers — one led by Reinhard Genzel of the Max Planck Institute for Extraterrestrial Physics in Germany and the other by Andrea Ghez of the University of California at Los Angeles — have been monitoring the motions of stars closest to the black hole with telescopes in Chile and Hawaii. Could these stars be the former binary partners of hypervelocity stars? "It is certainly possible," says Ghez.

In fact, some of the stars nearest to the galactic center, dubbed "S-stars," are in highly elongated orbits. These orbits are consistent with the idea that the stars were captured into orbit around the black hole during a close approach while their partners were flung out. Not all short-period stars have eccentric orbits, however. But that could be because their orbits have evolved over time through interactions with other stars or stellar-mass black holes in the vicinity. "The number of observed S-stars is consistent with the estimated number of hypervelocity stars, which is quite uncertain of course," says Genzel. His conclusion: "Currently the observational evidence does favor the idea that the hypervelocity stars are the brothers and sisters of the S-stars."

Meanwhile, Brown and others are looking for additional members of the tribe. Astronomers have yet to search the entire southern sky. If they gather a much larger sample of hypervelocity stars, the spread of the stars' locations and speeds could not only point to their origin but also help astronomers trace the shape and size of the galaxy's outer halo.

For a simulation of interacting galaxies and the stars they fling out, visit www.Astronomy.com/toc.

A new day dawns for Hubble

Shuttle astronauts installed two new instruments, fixed two older ones, and upgraded the space telescope's gyroscopes and batteries. **by Richard Talcott**

On the afternoon of May 11, space shuttle Atlantis roared off Launch Pad 39A at Florida's Kennedy Space Center. At the time, the Hubble Space Telescope was passing overhead. Yet it would take Atlantis 2 days to catch up with the orbiting observatory and get down to the important work of Servicing Mission 4. The goal: upgrade Hubble by installing new instruments, repairing old ones, and replacing worn-out parts. The result: a resounding success.

After 19 years in the harsh environment of low Earth orbit, Hubble was showing its age. Two of its four science instruments — the Space Telescope Imaging Spectrograph (STIS) and the Advanced Camera for Surveys (ACS) — had suffered devastating power failures. STIS no longer worked. And ACS, which still operated on one of its three channels, had lost its ability to take beautiful images.

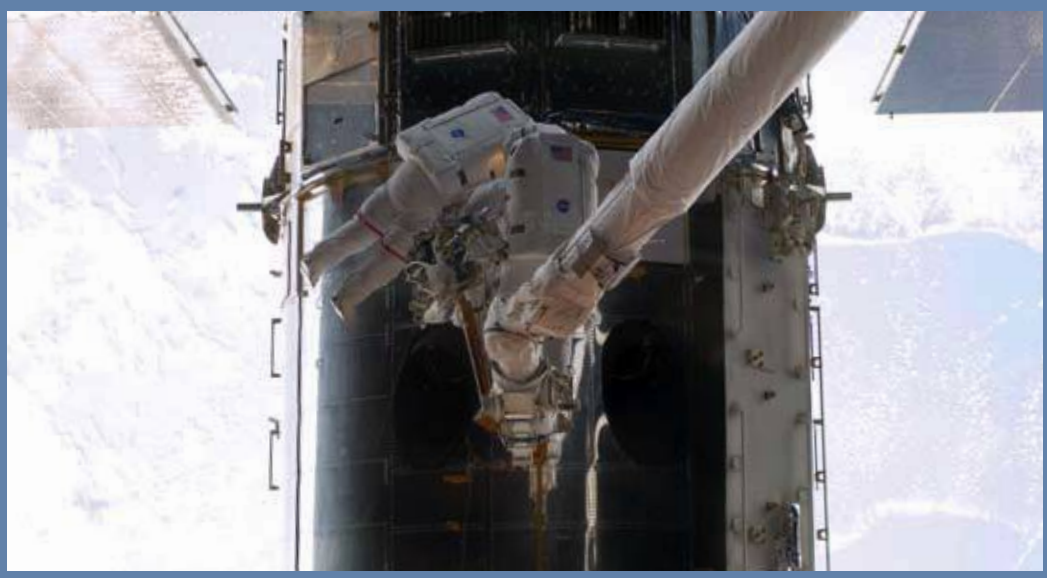
To compound the troubles, three of Hubble's six gyroscopes had failed, and two of three Fine Guidance Sensors were ailing. The telescope needs at least two gyros and two sensors to point accurately, so it was facing a possible crisis in the not-too-distant future.

To top it off, the telescope's main Science Instrument Command and Data Handling unit failed September 27, 2008. This unit provides all the electronics needed to operate the science instruments from the ground and send science and engineering data from Hubble back to Earth.

The craft has two such units — one active and an unpowered backup. Although NASA had switched to the backup, it did not want to leave the orbiting observatory without a spare. The space agency had postponed the servicing mission from its scheduled October 2008 launch until engineers could test and deliver a backup system to Kennedy Space Center.

Rocketing into space from Cape Canaveral May 11, space shuttle Atlantis and its seven astronauts set off to repair the Hubble Space Telescope.

^ **Repairing** the Space Telescope Imaging Spectrograph (STIS) occupied nearly all of the fourth spacewalk, in part because of a balky handrail. Here, Michael Good (on the shuttle's robotic arm) and Michael Massimino (just to his right) work on STIS inside Hubble. All images by NASA



> **Wide Field Camera 3** finds its new home inside Hubble, as astronauts John Grunsfeld (left) and Andrew Feustel wrap up the camera's installation during the first spacewalk.

Hubble stands tall in the cargo bay of Atlantis. The crew captured this scene after Mission Specialist Megan McArthur grabbed the telescope with the shuttle's robotic arm.

Atlantis crew members pose the day after they released Hubble. Sitting in the front row (left to right) are Gregory Johnson, Scott Altman, and Megan McArthur. Behind them (left to right) are Michael Good, Michael Massimino, John Grunsfeld, and Andrew Feustel.

The fifth spacewalk included several maintenance tasks. In this scene, John Grunsfeld (left) and Andrew Feustel prepare to install new thermal blankets on the space telescope.

Rendezvous with destiny

Science operations aboard Hubble continued until launch. At that point, mission controllers at NASA's Goddard Space Flight Center in Greenbelt, Maryland, began to shut the telescope down. They put its science instruments into standby mode, closed the aperture door, and retracted the two large high-gain-antenna masts.

This was the Hubble that awaited Atlantis and its astronauts as they approached May 13. Commander Scott Altman and Pilot Gregory Johnson brought Atlantis up next to the telescope. Mission Specialist Megan McArthur then grappled Hubble with the shuttle's robotic arm, brought it into the payload bay, and locked it down. This would be Hubble's home for the next 6 days.

During five spacewalks lasting a total of 36 hours and 56 minutes, two teams of mission specialists repaired the ailing craft. John Grunsfeld and Andrew Feustel worked days 1, 3, and 5, while Michael Massimino and Michael Good donned their spacesuits on days 2 and 4. The teams accomplished all of NASA's goals for the mission. But — as always seems to happen when working in space — there were a few glitches.

One problem came during the first spacewalk and threatened the installation of what will become Hubble's primary camera. To install the Wide Field Camera 3 (WFC3), Grunsfeld and Feustel first had to remove the Wide Field and Planetary Camera 2 (WFPC2). After more than 15 years on Hubble, however, WFPC2 didn't want to leave.

The astronauts had a difficult time removing a bolt that held the camera in place. They tried a variety of tools and even applied extra force to the bolt, all to no avail. If the bolt had broken, they wouldn't have been able to remove the old camera and install the new one. The pair eventually retrieved a ratchet tool, reconfigured it, and managed to remove the bolt. The rest of the removal and WFC3's installation went perfectly.

New views of the heavens

Hubble scientists have high hopes for the new camera. WFC3 will observe the universe at ultraviolet, visible, and near-infrared wavelengths simultaneously. With this capability, the camera can

Richard Talcott *is a senior editor of* Astronomy.

Hubble drifts away after Atlantis' crew finished servicing it. The space telescope should be set for at least 5 more years of discoveries.

view a galaxy and see its hot young stars (which radiate mostly in the ultraviolet) and cool old stars (which glow in the red and near-infrared) at the same time. With its heightened sensitivity and wide field of view, WFC3 will far outclass any of Hubble's previous cameras.

During its lifetime, WFPC2 took a few hundred thousand images of the cosmos. Among them were some of Hubble's most iconic, including the "pillars of creation" in the Eagle Nebula and the Hubble Deep Field. Atlantis brought the camera back to Earth, where it will go on permanent display in the Smithsonian Institution's National Air and Space Museum in Washington, D.C.

Astronauts installed Hubble's other new science instrument — the Cosmic Origins Spectrograph (COS) — on the third spacewalk. It replaces the Corrective Optics Space Telescope Axial Replacement — the "glasses" installed during the first servicing mission to compensate for the telescope's misshapen primary mirror.

COS breaks down incoming light into its component colors, revealing an object's temperature, composition, density, and velocity. Astronomers will use COS' ultraviolet sensitivity to explore distant galaxies and quasars. Researchers expect that the results will give them a keener insight into the universe's structure and evolution.

The third spacewalk also saw astronauts install new electronics in the ACS. The electronics worked, but they restored only the camera's wide-field channel. The high-resolution channel remains inoperable. Fortunately, scientists use the wide-field channel more than any other. Since astronauts installed ACS in 2002, the wide-field channel garnered 70 percent of the observation time.

The most complex repair took place on the fourth spacewalk when Massimino and Good fixed STIS. NASA did not design the spectrograph for repair. The task required the astronauts to painstakingly remove 111 screws after affixing a "capture plate" over the instrument's access panel to prevent any screws from floating free. Oddly enough, this part of the repair went smoothly, but the astronauts had trouble removing a handrail to attach the capture plate. In the end, Massimino simply yanked the handrail off.

Ready for the long haul

The astronauts encountered only one other significant problem during the repairs, while replacing the gyroscopes. The gyros are packed in pairs inside boxes called Rate Sensor Units. Atlantis brought along three replacement units, but one refused to fit into its slot. The astronauts managed to place a spare unit into the slot, so the telescope now has six working gyros.

The other key upgrades went well. Hubble now sports a new Science Instrument Command and Data Handling unit, a new Fine Guidance Sensor, two new batteries, and three new thermal blankets.

The astronauts also attached the Soft Capture Mechanism to Hubble's back end. This allows a next-generation vehicle to capture the spacecraft and send it on a controlled reentry into Earth's atmosphere. But this fate lies at least 5 years in the future. No one was thinking about that day when McArthur released Hubble back into space May 19.

Atlantis touched down at Edwards Air Force Base in California May 24, 2 days later and a continent away from its scheduled landing. Persistent tropical rains in Florida had kept the shuttle in space overtime. Still, NASA couldn't be happier. Atlantis' 5.3-million-mile (8.5 million kilometers) journey accomplished all of the tasks NASA set out to achieve. And Hubble is now back in the peak of health, ready to push the frontiers of astronomical observation even deeper.

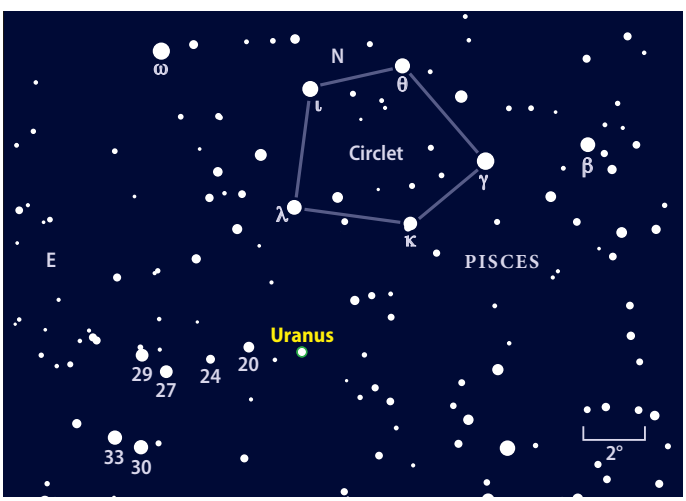
The Sky this Month

Martin Ratcliffe and Alister Ling describe the solar system's changing landscape as it appears in Earth's sky.

September 09

Uranus' turn in the Sun

Blue-green Uranus may not look like much through a telescope, but you can see its small disk at magnifications of 100x and more. Even this close-up look from the Voyager 2 spacecraft fails to reveal much detail. NASA/JPL



Uranus peaks in mid-September, when it glows at magnitude 5.7 in Pisces. Keen observers might glimpse it without optical aid. *Astronomy*: Roen Kelly

With the autumnal equinox arriving this month, sky-gazers have about 12 hours of possible night-sky viewing. Jupiter manages to fill most of those hours. The giant planet dominates September's sky. Its brilliant glow hangs low in the southeast after sunset, climbs high in the south before midnight, and sets around the time morning twilight begins.

Two other planets, Uranus and Neptune, remain binocular targets in Jupiter's general vicinity. Early morning risers can watch for Venus and Mars along with a brief appearance by innermost Mercury.

September begins and ends with **Jupiter** near a bright gibbous Moon. On September 1, Jupiter lies nearly 10° east of the Moon. The two return to nearly the same positions September 28. Jupiter lies in the constellation Capricornus the Sea Goat, a region devoid of bright stars. Still, at magnitude –2.8, the planet doesn't need any help to stand out.

Jupiter reached opposition in August. It then lay closest to Earth for the year and appeared largest through a telescope. This month, its distance increases slowly, and the giant planet's disk shrinks about 5 percent. On September 15, it spans 47" across the equator and 44" through the poles. You can easily see this squashed appearance through any telescope.

40 Uranus reaches opposition
45 Meteor watch
45 Rising Moon
46 When to view the planets
46 Jupiter goes moonless
46 Comet search
47 Locating asteroids
47 Venus joins the Beehive

Visible to the naked eye
Visible with binoculars
Visible with a telescope

But Jupiter offers a lot more. Its massive atmosphere displays a wealth of intriguing features. The first things you'll notice are two dark equatorial belts sandwiching a brighter equatorial zone. On nights when Earth's normally turbulent atmosphere settles down and the seeing steadies, several more-subtle bands will come into view. Details within these belts show up through 6-inch and larger scopes. Because Jupiter rotates so quickly (in less than 10 hours), you can see changes in the planet's appearance in as few as 10 minutes.

Also look for the Great Red Spot. This atmospheric storm, which is bigger than planet Earth, appears more subtle

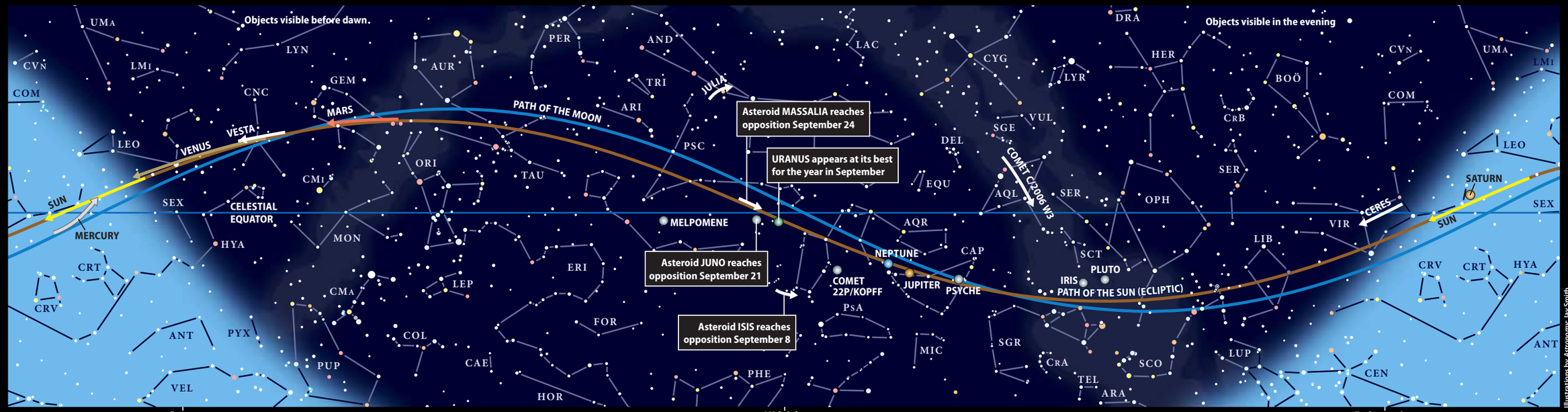
— *Continued on page 45*

Planets in September 09

This map unfolds the entire night sky from sunset (at right) until sunrise (at left).
Arrows and colored dots show motions and locations of solar system objects during the month.

Astronomy magazine

Path of the planets



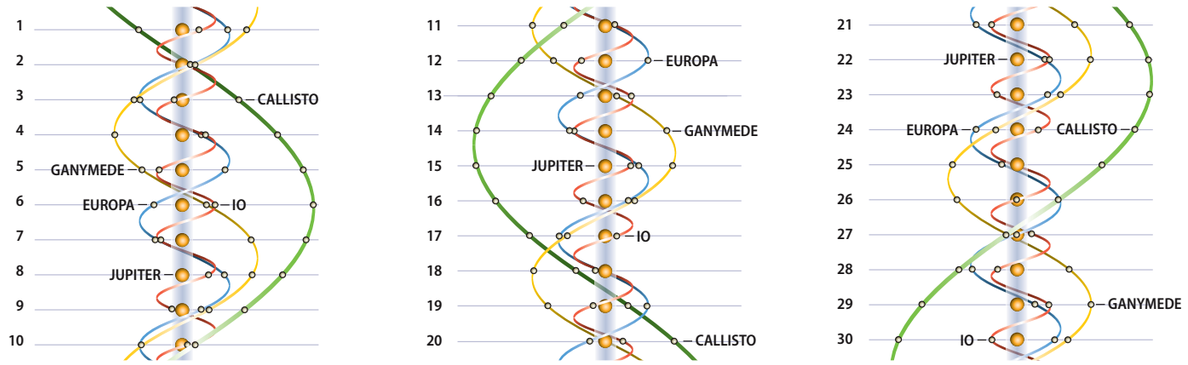
MOON PHASES

To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.
Note: Moons vary in size due to distance from Earth and are shown at 0h Universal Time.

PLANETS	MERCURY	VENUS	MARS	• CERES	JUPITER	SATURN	URANUS	NEPTUNE	• PLUTO
Date	September 30	September 15	September 15	September 15	September 15	September 30	September 15	September 15	September 15
Magnitude	0.7	–3.9	0.9	8.8	–2.8	1.1	5.7	7.8	14.0
Angular size	8.4"	11.9"	6.2"	0.4"	47.3"	15.9"	3.7"	2.3"	0.1"
Illumination	23%	87%	89%	99%	100%	100%	100%	100%	100%
Distance (AU) from Earth	0.798	1.407	1.519	3.489	4.165	10.430	19.093	29.135	31.546
Distance (AU) from Sun	0.314	0.719	1.504	2.625	5.032	9.447	20.098	30.027	31.707
Right ascension (2000.0)	11h28.8m	9h42.7m	6h54.0m	13h14.9m	21h24.4m	11h49.9m	23h41.4m	21h46.6m	18h02.2m
Declination (2000.0)	3°24'	14°29'	23°18'	–1°01'	–16°23'	3°16'	–2°53'	–13°51'	–17°58'

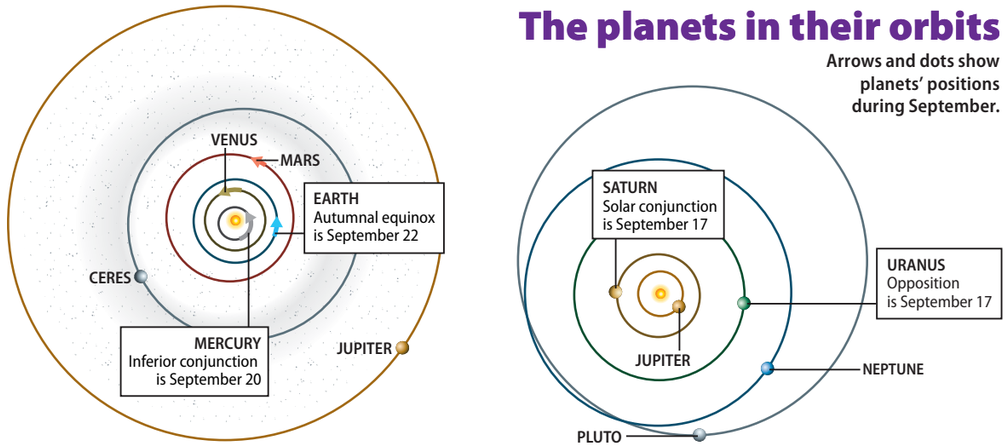
Jupiter's moons

Dots display positions of Galilean satellites at 11 P.M. EDT on the date shown.
South is at the top to match the view through a telescope.



The planets in their orbits

Arrows and dots show planets' positions during September.



StarDome

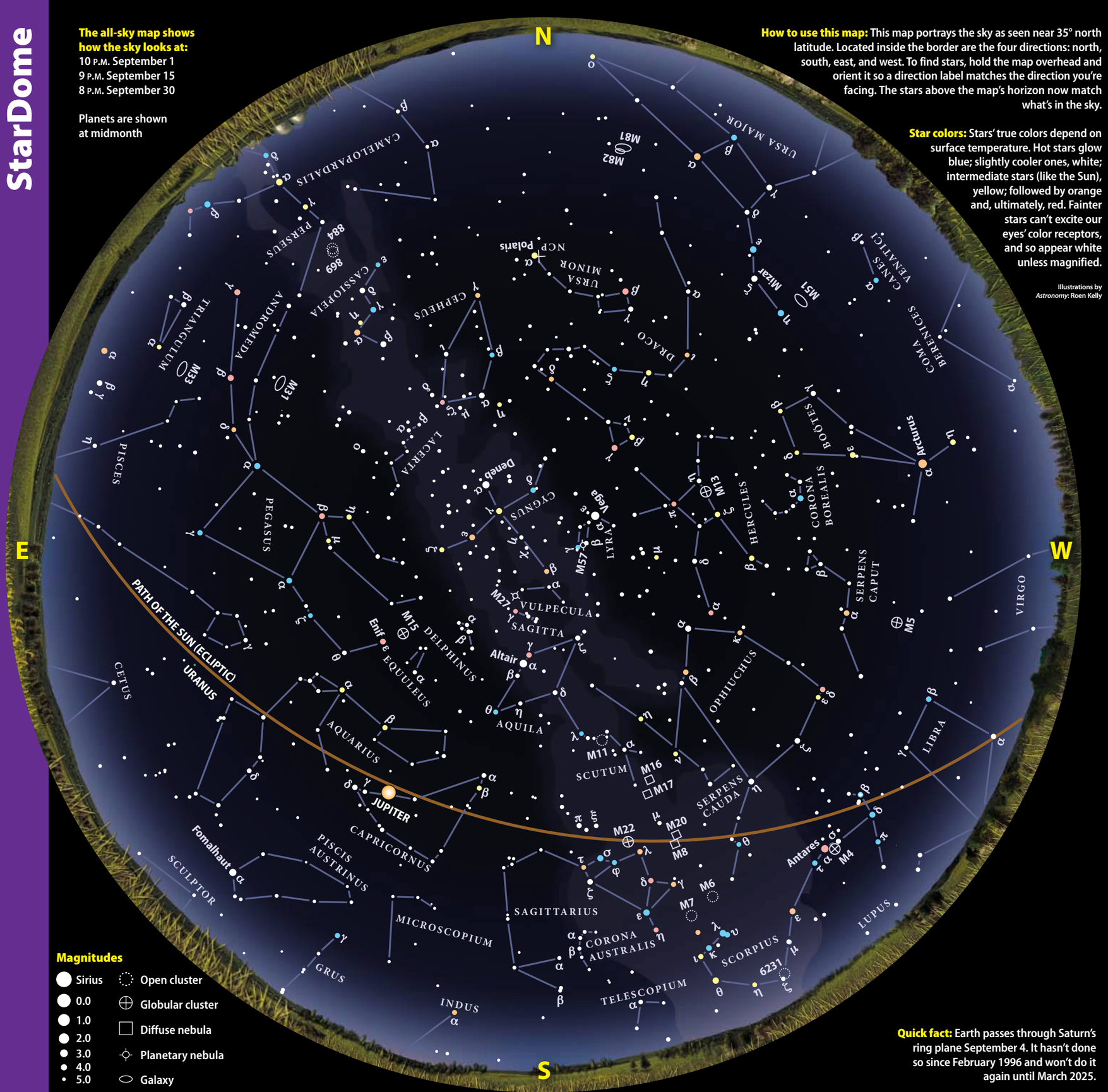
The all-sky map shows how the sky looks at:
10 P.M. September 1
9 P.M. September 15
8 P.M. September 30

Planets are shown at midmonth

How to use this map: This map portrays the sky as seen near 35° north latitude. Located inside the border are the four directions: north, south, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

Star colors: Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white unless magnified.

Illustrations by *Astronomy*: Roen Kelly



Magnitudes

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

Quick fact: Earth passes through Saturn's ring plane September 4. It hasn't done so since February 1996 and won't do it again until March 2025.

September 09

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

Calendar of events

2 The Moon passes 3° north of Jupiter, 5 P.M. EDT

Special observing date

2/3 Jupiter will appear without any Galilean moons during the overnight hours.

3 The Moon passes 3° north of Neptune, 3 A.M. EDT

4 Earth passes through Saturn's ring plane, 9 A.M. EDT

Full Moon occurs at 12:03 P.M. EDT

5 The Moon passes 6° north of Uranus, 5 P.M. EDT

6 Mercury is stationary, 4 P.M. EDT

8 Asteroid Isis is at opposition, 6 P.M. EDT

11 Pluto is stationary, noon EDT

Last Quarter Moon occurs at 10:16 P.M. EDT

12 Asteroid Pallas is in conjunction with the Sun, 8 P.M. EDT

13 The Moon passes 1.1° north of Mars, noon EDT

16 The Moon is at perigee (226,212 miles from Earth), 3:56 A.M. EDT

16 The Moon passes 3° south of Venus, 2 P.M. EDT

17 Uranus is at opposition, 6 A.M. EDT

Saturn is in conjunction with the Sun, 2 P.M. EDT

18 New Moon occurs at 2:44 P.M. EDT

20 Mercury is in inferior conjunction, 6 A.M. EDT

Venus passes 0.5° north of Regulus, 6 A.M. EDT

21 Asteroid Juno is at opposition, 4 A.M. EDT

22 Autumnal equinox occurs at 5:19 P.M. EDT

24 The Moon passes 0.8° north of Antares, 2 A.M. EDT

Asteroid Massalia is at opposition, 6 A.M. EDT

26 First Quarter Moon occurs at 12:50 A.M. EDT

27 The Moon is at apogee (251,302 miles from Earth), 11:32 P.M. EDT

28 Mercury is stationary, 2 P.M. EDT

29 The Moon passes 3° north of Jupiter, 8 P.M. EDT

30 The Moon passes 3° north of Neptune, 9 A.M. EDT

See tonight's sky in Astronomy.com's STARDOME

Astronomy magazine

— *Continued from page 40*

than its name implies. The feature often lies on the planet's farside or near the limb as seen from Earth, but if it's near the middle of the Earth-facing hemisphere, you should be able to spot it.

Jupiter's Galilean moons offer another treat for small-scope owners. These four bright points of light orbit Jupiter in periods ranging from 1.77 to 16.69 days. Their constant motions mean they show different arrangements from night to night, often from hour to hour.

But the moons do something the night of September 2/3 they won't do again for a decade. For nearly 2 hours, Jupiter will appear without any obvious moon. This situation lasts from 12:43 A.M. to 2:29 A.M. EDT September 3 (9:43 P.M. to 11:29 P.M. PDT September 2). During this period, Europa and Ganymede pass in front of Jupiter while Io and Callisto hide behind it. The next time Jupiter's moons pull a similar disappearing act comes in 2019.

If you swing a telescope toward Jupiter as darkness falls September 2, Europa and Ganymede lie near each other just off the planet's eastern limb. Meanwhile, Io lies west of the planet, and Callisto already has slid behind Jupiter. Over the next few hours, all three visible moons will move closer to Jupiter.

Io disappears at 11:43 P.M. EDT as it passes behind Jupiter's limb. Europa begins to transit across Jupiter's face at 11:58 P.M. EDT, and Ganymede follows suit at 12:43 A.M. EDT. Less than 15 minutes after Ganymede's transit begins, Europa's dark shadow appears north of Ganymede. The moonless Jupiter returns to some semblance of normality when Io exits Jupiter's shadow at 2:29 A.M. EDT. For those of you who like to watch shadow transits, Ganymede's shadow starts crossing Jupiter's disk at 2:42 A.M. EDT.

Jupiter provides a convenient guide for tracking down

Martin Ratcliffe *provides professional planetarium development for Sky-Skan Inc. in Nashua, New Hampshire. Meteorologist* **Alister Ling** *works for Environment Canada in Edmonton, Alberta.*

Rising **Moon**

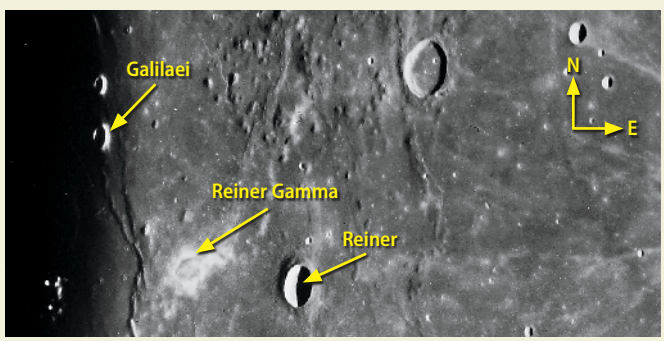
Go for Galileo's lunar legacy

In this International Year of Astronomy, it seems appropriate that we seek the lunar crater named in honor of Galileo. Typically, the higher a person's standing in the early history of science or philosophy, the more impressive his or her lunar feature. For example, most lunar observers can instantly locate Copernicus, Kepler, and Tycho.

Yet the crater Galilaei is half the size and much less prominent than the one named for his friend and student, Reiner. Appropriately, however, the two appear as isolated islands near each other in the large western "sea" named Oceanus Procellarum.

Spanning 10 miles, Galilaei is a classic sharp-rimmed crater. The sharpness tells astronomers that this crater is relatively young, although that only means it formed within the past 3.5 billion years.

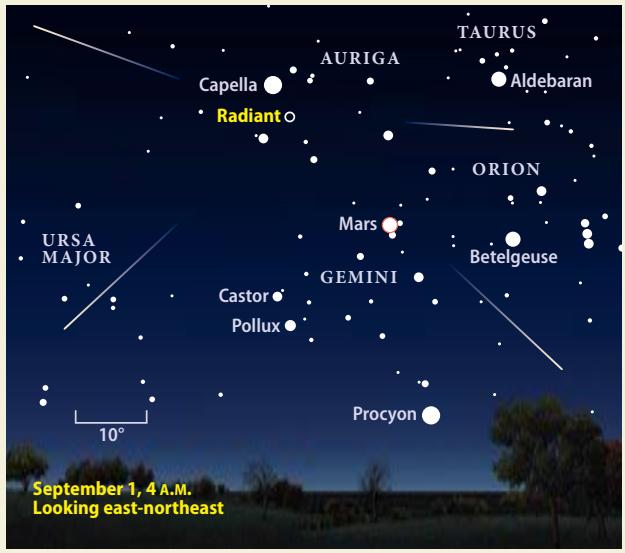
Sunrise on the Moon is timed perfectly for viewing Galilaei the night of September 1/2. Look for a pair of white chips along the terminator (the day-night dividing line) just north of the lunar equator. Galilaei is the southernmost of these two craters. Notice the sinuous rille that runs through them. The craters break the rille — solid evidence that the rille formed first and the impacts came afterward.



The lunar crater Galilaei measures 10 miles across, barely half the size of its neighbor, Reiner. Look for these two, along with the mysterious Reiner Gamma, in early September. *Consolidated Lunar Atlas*/UA/LPL

By September 3, a splotchy-white feature called Reiner Gamma shows up between Galilaei and Reiner. Like similar markings on the Moon's farside, it is not a topographic feature but has a fairly strong magnetic field. Planetary scientists still don't agree on what it is.

Meteor watch



The Alpha Aurigid meteor shower peaks September 1. Observers with clear dark skies could see up to 5 Aurigids per hour in the hour or two before dawn lightens the sky. *Astronomy:* Roen Kelly

Auriga hosts September's top shower

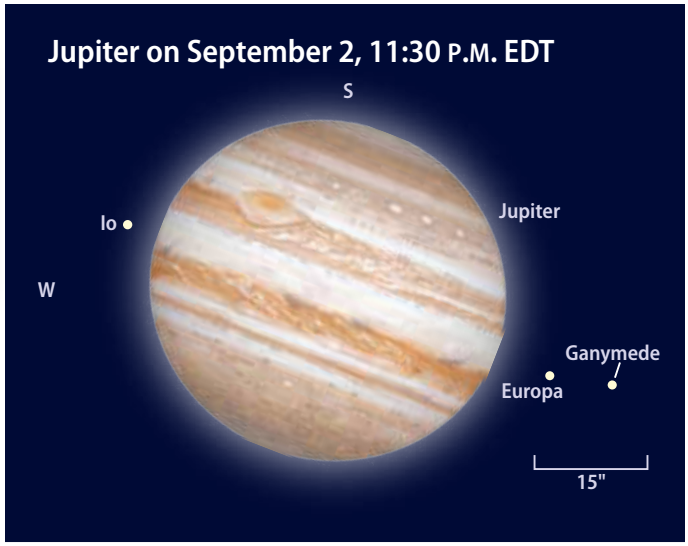
Following the August Perseid meteor show, September activity dies down. On any clear night at any time of year, a few random meteors will dart sporadically across the sky. That will be the case in September, with one exception.

The only shower with much chance of a decent display is the Alpha Aurigids. This minor event may deliver up to 5 meteors per hour at its peak before dawn September 1. Watch between 3:30 A.M. local daylight time, when the waxing gibbous Moon sets, and 5 A.M., when twilight starts to break.

Although enhanced rates occurred in 1935, 1986, 1994, and 2007, astronomers don't predict anything great this year. Still, minor showers occasionally produce major surprises, so it's worth keeping an eye out.

When to view **the planets**

EVENING	MIDNIGHT	MORNING
Jupiter (southeast)	Jupiter (south)	Mercury (east)
Uranus (east)	Uranus (south)	Venus (east)
		Mars (east)
		Saturn (east)
		Uranus (west)



Jupiter will look odd the night of September 2/3, when all four Galilean moons disappear. This illustration sets the scene about 75 minutes before Io, Europa, and Ganymede join Callisto in hiding. *Astronomy*: Roen Kelly

the solar system's outermost planet, **Neptune**. Grab your binoculars, and point them at Jupiter. Now place Jupiter near the right edge of the field, and you should see a widely spaced pair of bright stars left of center. Delta (δ) Capricorni lies to the left (east) of Gamma (γ) Cap and shines a magnitude brighter. You could fit 3.5 Full Moons between this pair.

Starting at Delta, move about 3 Moon-widths north to find a line of three fainter stars. The brightest and northernmost one is 42 Cap, which shines at 5th magnitude. If you move 3 Moon-widths east of 42 Cap in early September, you should see Neptune. It glows at magnitude 7.8, considerably fainter than the stars that led you there. By the end of September, the gap between Neptune and 42 Cap has shrunk to 2 Moon-widths.

Neptune's inner neighbor, **Uranus**, reaches opposition and peak visibility September 17. Binoculars can show it to you after darkness falls, when the planet already appears well above the southeastern horizon. Uranus shines at magnitude 5.7 and lies due south of the Circlet asterism in Pisces. It inhabits a sparse region of the sky — no star within 5° shines noticeably brighter than the planet.

To find Uranus, start at Lambda (λ) Piscium, the star that marks the Circlet's southeastern corner. Then swing your binoculars about 5° south to find a widely spaced pair of objects. The object on the right (west) is Uranus; the eastern point of light is the star 20 Piscium. The gap between the pair nearly doubles during September. If you aim a telescope at Uranus and boost the magnification above 100x, you should see a blue-green disk measuring 3.7" across. If the image appears unsteady, wait until closer to midnight when the planet is higher in the sky.

Mars rises a little past midnight along with the background stars of Gemini. The Twins normally host two 1st-magnitude objects, the stars Castor and Pollux, but Mars makes it three. The Red Planet appears a bit brighter than the stars and offers a nice color contrast: Castor shines nearly pure white while Pollux has a yellow-orange hue.

By the time twilight begins, Mars appears about halfway to the zenith. The steadier air at these elevations might allow observers with 8-inch or larger telescopes to see some faint details on the martian

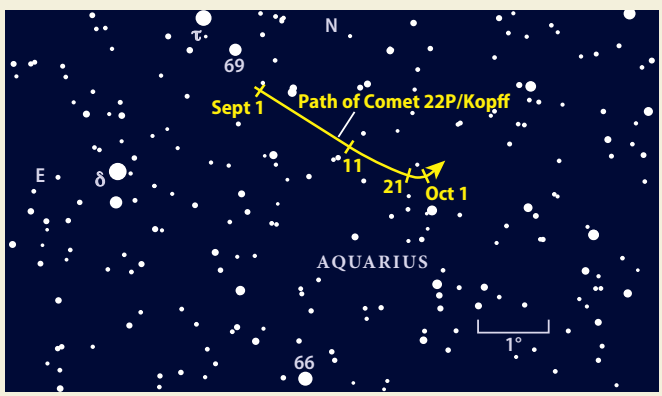
Comet search

Catch Comet Kopff one more time

When the Moon is gone from the sky in mid-September, many deep-sky observers will target Comet 22P/Kopff. Although deep-sky observers often shy away from solar system objects, this primordial iceball could be an exception. Through a telescope, observers can compare the brightness and structure of a comet to those of gas clouds and galaxies. And because comets move relative to the starry background, fresh comparison objects pop up frequently.

In September, the large Helix Nebula (NGC 7293) lies just a few degrees south of 10th-magnitude 22P/Kopff. Both will show up best under a dark country sky. The Helix is a planetary nebula, so it has a region at its center that was swept clean as a dying star puffed off its outer layers. Compare the Helix's central hole with the comet, which grows brighter toward its core. Also look closely at the comet's edges — one side will have a high contrast where the Sun's radiation has compressed the released dust. On the opposite side, the brightness fades gradually as the dust particles fan out.

To get the best views of the two objects, wait until 11 P.M. That gives them a chance to climb comfortably above the southern horizon and away from the thickest layers of our turbulent atmosphere.



Comet 22P/Kopff should glow around 10th magnitude as it continues westward against the background stars of Aquarius. *Astronomy*: Roen Kelly

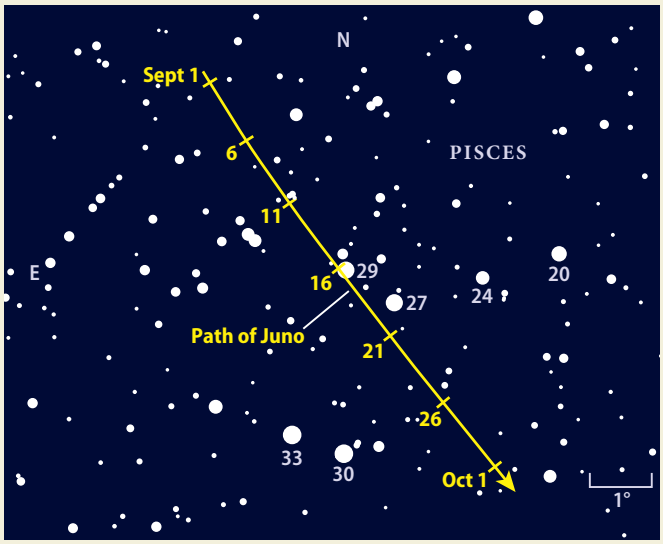
Comet 22P/Kopff returns to the inner solar system every 6.4 years (the "P" in its designation means periodic). It is on its 16th pass through our neighborhood since German astronomer August Kopff discovered it in 1906.

Jump on the Juno bandwagon

Making its best appearance since 2005, asteroid 3 Juno brightens to magnitude 7.6 as it reaches opposition this month. If you live in the suburbs, you can walk outside your house and pick it up through binoculars in less than 5 minutes. All you need is a rough idea of where to look. Except for a handful of useful guideposts, the rest of the background stars glow considerably fainter than our quest.

To find Juno, face southeast in late evening and look for the Great Square of Pegasus. Then, slide your gaze down past Pisces' lovely Circlet asterism to find a tall, thin box of 4th- and 5th-magnitude stars that fits inside a binocular field of view. This box lies at the southern border of Pisces and displays the brightest stars on the finder chart at right. Now you're set to track Juno during September.

Of the first four asteroids discovered, 3 Juno is by far the smallest. It's only half the size of Pallas and Vesta and barely one-quarter the diameter of Ceres. But when it comes to an asteroid's brightness, the key is its distance from both the Sun and Earth. In 2009, Juno comes within 110 million miles of Earth and 200 million miles of the Sun. In 2012, it will lie near the far point of its oval orbit and glow softly at magnitude 10.2. We likely won't feature Juno again in this column until 2015, when it climbs to magnitude 8.1.



Juno glows brighter than at any time since 2005 when it reaches opposition this month. This modest asteroid — the smallest of the solar system's "Big Four" — slides southwest through Pisces. *Astronomy*: Roen Kelly

disk. By late September, Mars appears 7" across.

More casual observers — or students looking for a nice science project — might want to plot Mars' path on a star chart to learn about its motion through the sky. The planet currently treks eastward relative to the background stars. This so-called direct motion continues until December, when Mars makes a hairpin turn and starts moving to the west (or retrograde). The change in direction results from Earth overtaking the Red Planet on our smaller and faster orbit around the Sun.

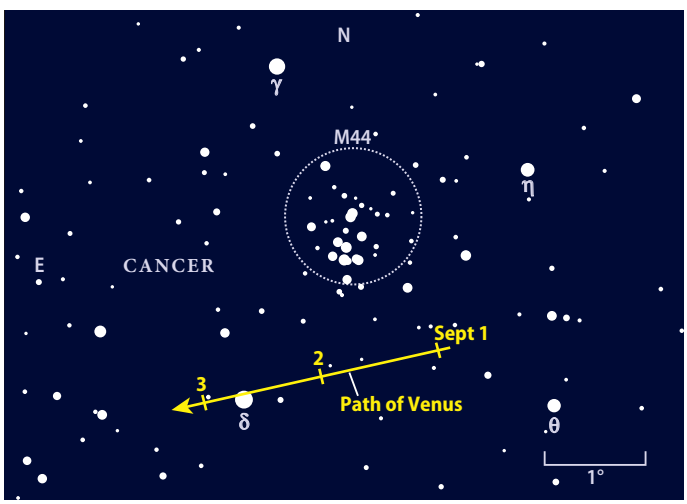
An attractive sight awaits early risers September 13. That morning, a waning crescent Moon snuggles within a couple degrees of Mars.

On the mornings of September 1 and 2, **Venus** appears just 1° south of the Beehive star cluster (M44) in Cancer the Crab. The cluster will be hard to pick out as the objects rise. The best time to look will be around 5 A.M. local daylight time, after they climb away from the horizon but before twilight starts to brighten the sky. Binoculars will offer the best views. You'll have no trouble spotting Venus — the brilliant planet shines at magnitude –3.9 and easily outshines all the other points of light in the sky.

Venus slides eastward against the background stars during September. By the 20th, the "morning star" parks next to Regulus in Leo the Lion. You could barely fit a Full Moon between the objects. Venus outshines the 1st-magnitude star by 100 times (or five magnitudes).

Venus' telescopic appearance changes slowly. During September, the planet's diameter shrinks from 13" to 11" while its phase fattens from 83 percent to 90 percent lit.

As September closes, morning twilight hosts a fine collection of planets. Venus stands 10° above **Mercury**, the latter of which rises more than an hour before the Sun. Mercury shines brightly, at magnitude 0.7, and should show up against the twilight. A telescope will reveal the planet's 8"-diameter disk, which appears about one-quarter lit. Mercury's visibility will improve by early October.



Brilliant Venus passes just south of the Beehive star cluster (M44) on September's first 2 mornings. The planet shines nearly 1,000 times brighter than the combined light of the cluster's few hundred stars. *Astronomy*: Roen Kelly

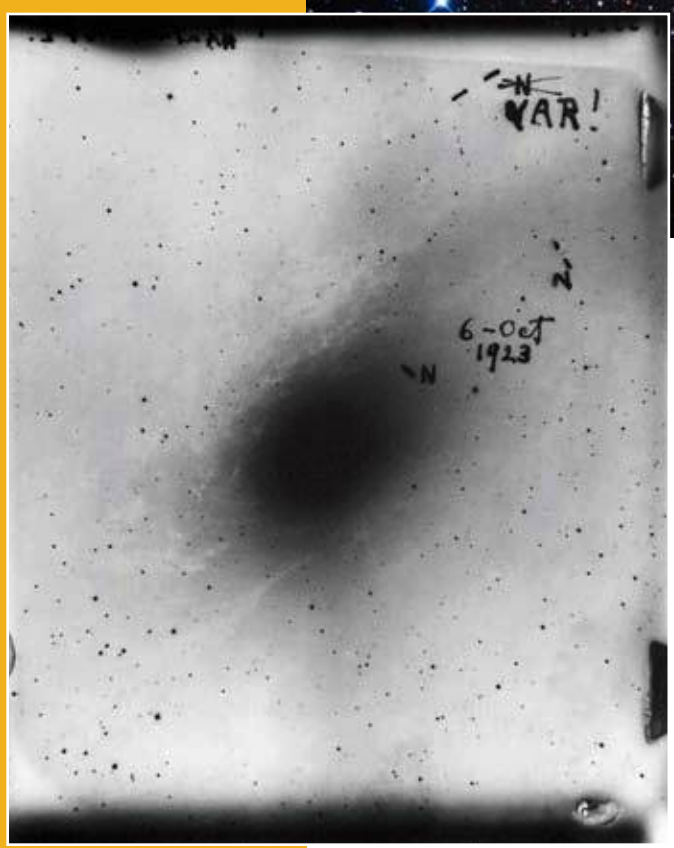
Saturn follows a track similar to the two inner planets as they climb in the eastern sky, although the ringed planet actually lies far across the solar system. Saturn's reappearance before dawn follows its conjunction with the Sun September 17. The 1st-magnitude planet won't be easy to spot in bright twilight, however. You'll be better off waiting until October to view it through your telescope.

When you do, you'll see a side of the rings that has been out of sight for more than 13 years. On September 4, while the Sun hides Saturn from view, Earth passes through the ring plane. Within the next 2 months, we'll begin to see the rings' northern face for the first time since early 1996.

The stars that revealed the **vastness** of the universe

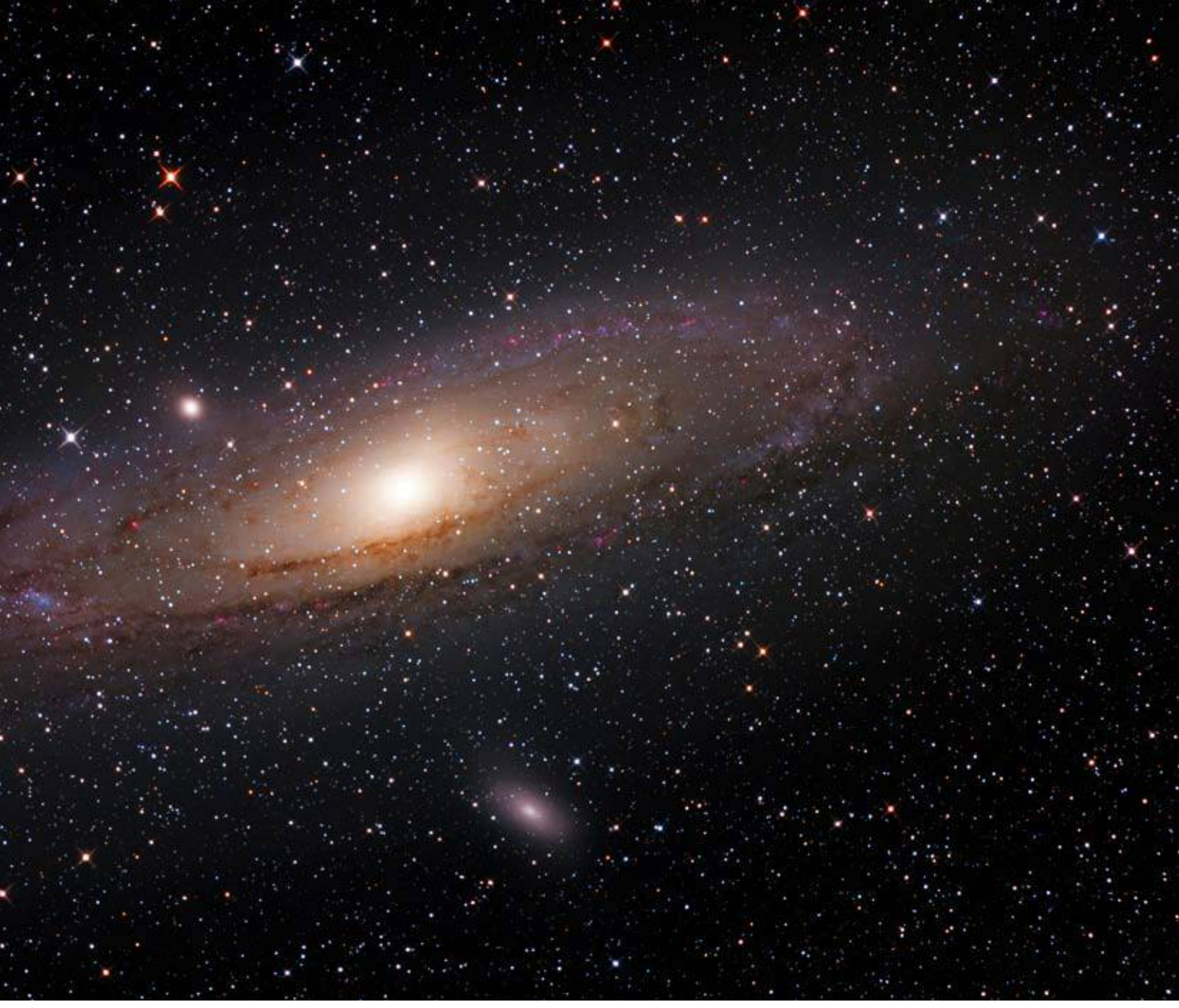
Cepheids are pulsating variable stars that astronomers use to measure cosmic distances. They remain at the heart of solving key cosmic riddles.

by Bruce Dorminey



In 1923, astronomer Edwin Hubble searched a photographic plate (right) of the Great Nebula in Andromeda. He marked several stars undergoing sudden brightening "N" for "nova." But Hubble realized one of the stars was a type of pulsating variable star, called a Cepheid, that could be used to estimate the nebula's distance. He excitedly wrote "VAR!" for "variable" near the star. Cepheids revealed that Andromeda was not a gas cloud, but a distant galaxy.

Main image: Bob and Janice Fera; Inset: Courtesy of The Observatories of the Carnegie Institution of Washington



Polaris, the stellar beacon at the handle-tip of the Little Dipper, frequently captures the attention of even casual night-sky observers. After reaching its present position near the North Celestial Pole about a millennium ago, Polaris also caught the eyes of both poets and explorers. Plying the open waters of an uncharted ocean, Columbus used his uncanny ability to do naked-eye fixes of Polaris' altitude to keep his expeditions on course to within about a degree of latitude. A little more than a century later, Shakespeare romanticized the North Star as "constant" and "true-fix'd." In truth, it is neither.

Only 430 light-years from Earth, Polaris represents the brightest nearby example of a classical Cepheid variable, a quirky and often-tumultuous class of pulsating supergiant stars. These stars, which vary in brightness over a given period of time, remain at the forefront of modern cosmology.

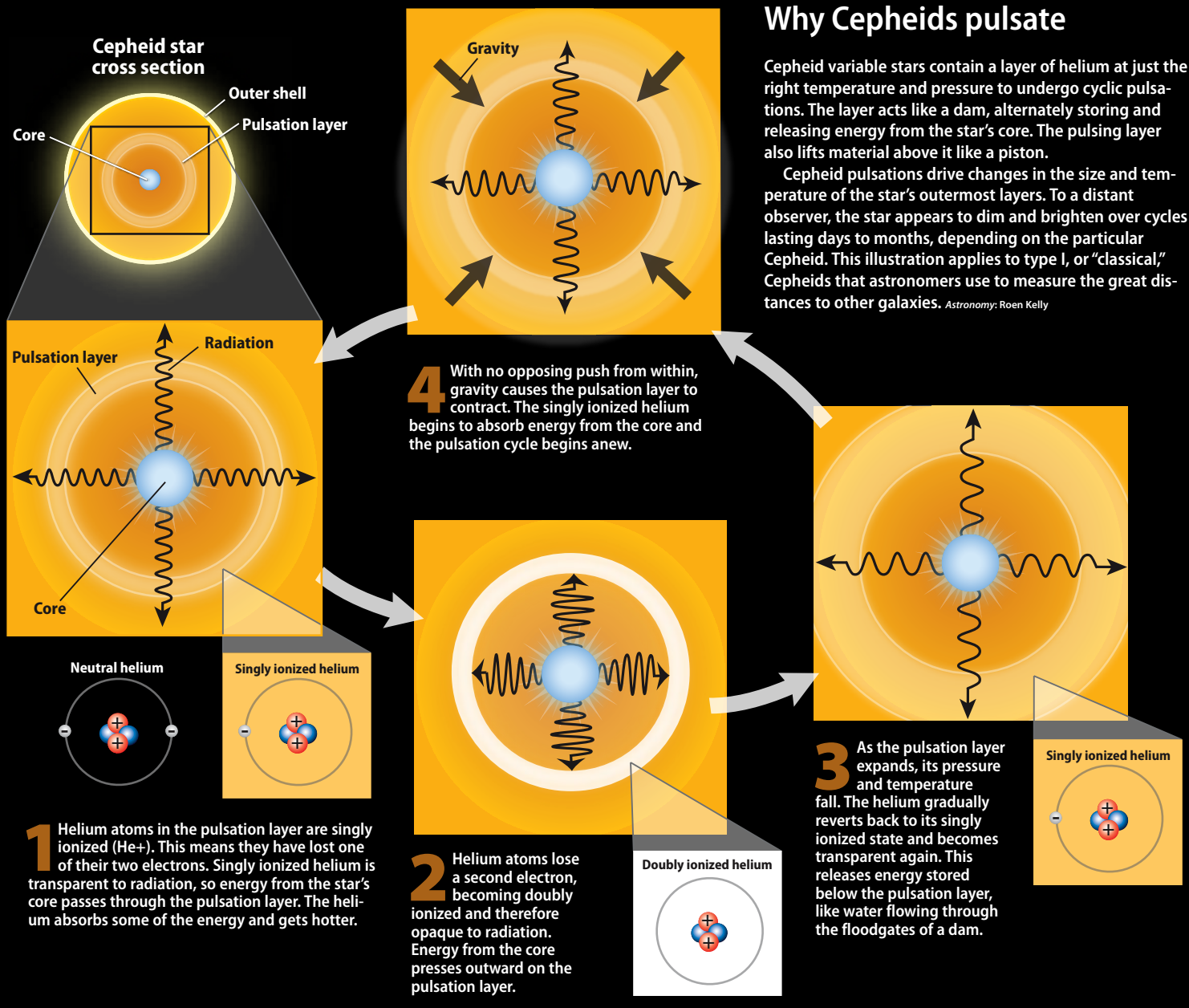
Astronomers discovered more than a century ago that they could deduce a Cepheid's light output (luminosity) based on the duration (period) of its cyclic brightness changes. Comparing the luminosity to the observed brightness provided a way to estimate the star's distance.

Researchers have continued to use Cepheids to calibrate and sharpen the suite of techniques — known as the cosmic distance scale — they employ to measure the universe. The ability to gauge cosmic distances precisely is critical to understanding everything from what's fueling post-Big Bang cosmic expansion to the ultimate fate of the universe.

Pulsating supergiants

Classical Cepheids vary in luminosity on a predictable schedule because processes in their extended stellar envelopes alternately store and release energy. (See "Why Cepheids pulsate," page 50.) As a result, the stars alternately shrink and expand, accompanied by variations in surface temperature and, therefore, brightness.

Cepheids take their name from the constellation Cepheus, where astronomers discovered the first example of this new class of variable stars, Delta Cephei.


Cepheid star cross section
Outer shell
Core
Pulsation layer
Gravity
Why Cepheids pulsate
Cepheid variable stars contain a layer of helium at just the right temperature and pressure to undergo cyclic pulsations. The layer acts like a dam, alternately storing and releasing energy from the star's core. The pulsing layer also lifts material above it like a piston.
Cepheid pulsations drive changes in the size and temperature of the star's outermost layers. To a distant observer, the star appears to dim and brighten over cycles lasting days to months, depending on the particular Cepheid. This illustration applies to type I, or "classical," Cepheids that astronomers use to measure the great distances to other galaxies. Astronomy: Roen Kelly
Pulsation layer
Radiation
Core
Neutral helium
Singly ionized helium
1 Helium atoms in the pulsation layer are singly ionized (He+). This means they have lost one of their two electrons. Singly ionized helium is transparent to radiation, so energy from the star's core passes through the pulsation layer. The helium absorbs some of the energy and gets hotter.
2 Helium atoms lose a second electron, becoming doubly ionized and therefore opaque to radiation. Energy from the core presses outward on the pulsation layer.
Doubly ionized helium
3 As the pulsation layer expands, its pressure and temperature fall. The helium gradually reverts back to its singly ionized state and becomes transparent again. This releases energy stored below the pulsation layer, like water flowing through the floodgates of a dam.
Singly ionized helium
4 With no opposing push from within, gravity causes the pulsation layer to contract. The singly ionized helium begins to absorb energy from the core and the pulsation cycle begins anew.

In 1908, Harvard College Observatory astronomer Henrietta Swan Leavitt first noted a relationship between the average brightness of Cepheids and the periods of their fluctuations. The brightest stars, Leavitt noted, had the longest periods. This relationship came to be called the period-luminosity function.

Classical Cepheids typically have periods of 1 to 100 days. By measuring the period, astronomers can estimate a Cepheid's luminosity — how much light it really emits — as opposed to its apparent brightness to an observer on Earth. And the difference between the intrinsic and apparent brightness reveals a Cepheid's distance, just as automobile headlights dim with increasing distance. Astronomers gained a "standard candle" for measuring the vast separation between celestial objects.

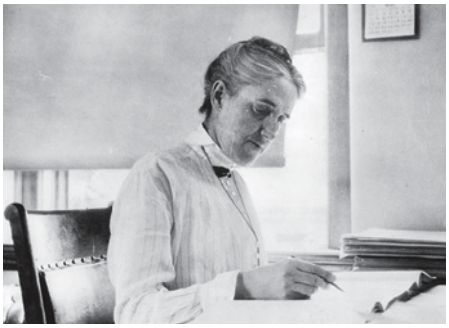
Cepheids live for a relatively short time — 50 to 60 million years — but shine 500 to 30,000 times brighter than the Sun. That makes them detectable with telescopes at the extreme distances to other galaxies. The best Cepheids for measuring galactic distances are those with the longest periods, on order of 10 to 100 days. "Those are the brightest and easiest to find," says Wendy Freedman, director of the Carnegie Observatories. "The most luminous are the rarest and the youngest."

With the period-luminosity relationship known, Cepheids proved their value. In 1923, American astronomer Edwin Hubble identified a Cepheid in the Great Nebula in Andromeda (M31), as it was known at the time. He eventually used Cepheids to estimate the nebula's distance and discovered that it was too far away to be part of our Milky Way. It was, in fact, the Andromeda Galaxy.

Climbing the ladder

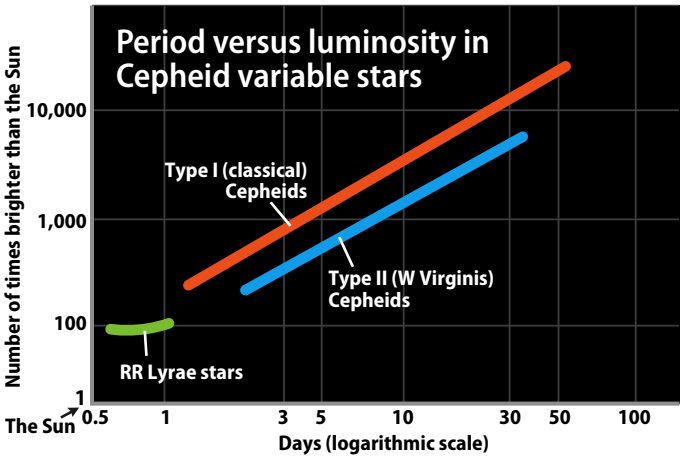
The Cepheid period-luminosity function is now one of multiple tools astronomers

Bruce Dorminey's *most recent* Astronomy *article was "Is our galaxy running out of gas?" (January 2009). He is the author of* Distant Wanderers: The Search For Planets Beyond The Solar System *(Springer, 2001).*



AIP Emilio Segre Visual Archives

Henrietta Swan Leavitt, then at the Harvard College Observatory, discovered that the brightest Cepheid variable stars took the longest to cycle through fluctuations in light output. This relationship provided a way to measure cosmic distances.



Cepheid variable stars undergo cyclic brightness changes. For all three types, astronomers can use the length of the pulsation cycle (period) to estimate the star's intrinsic brightness, or luminosity. Type I, or "classical," Cepheids are commonly used to measure distances to other galaxies.

Astronomy: Roen Kelly

The Hubble Space Telescope can resolve individual stars in other galaxies. In this Hubble image, Cepheid variables (in red circles) revealed that the galaxy I Zwicky 18 is 59 million light-years from Earth. The new Cepheid distance and other observations suggest I Zwicky 18 is older than astronomers previously thought. NASA/ESA/Alessandra Aloisi (ESA & STScI)

use to measure distances to stars and galaxies. Sometimes called the cosmic distance ladder, it allows measurements at ever larger distance scales.

Cepheids occupy one of the lowest rungs, providing a means to climb to higher and more distant rungs. Astronomers use one rung to calibrate estimates to the next one, "bootstrapping" successive techniques to greater distances.

For example, type Ia supernovae — exploding stars that can be used as a standard candle for measuring distance — are brighter than Cepheids and are therefore visible at much greater distances. So astronomers have searched for galaxies containing both Cepheids and type Ia supernovae. The Cepheid distance provides the means to interpret observations of the more far-flung supernovae. "Classical Cepheids are the bread and butter of distance indication measurements," says Michael Feast, an astronomer at the University of Cape Town in South Africa.

However, such translations are fraught with assumptions that introduce uncertainties into the measurements, like a yardstick whose markings have been obscured by age. For example, observing Cepheids and supernovae in distant galaxies is no trivial task. "Star fields are extremely crowded in those galaxies," Feast explains.

Astronomers must pick out the Cepheids and supernovae from thousands of other stars and measure their apparent brightnesses. "This is a complicated technical problem," Feast says. "It's not a totally straightforward measurement and contributes to the uncertainty in the final absolute brightness that you assign to the supernovae."

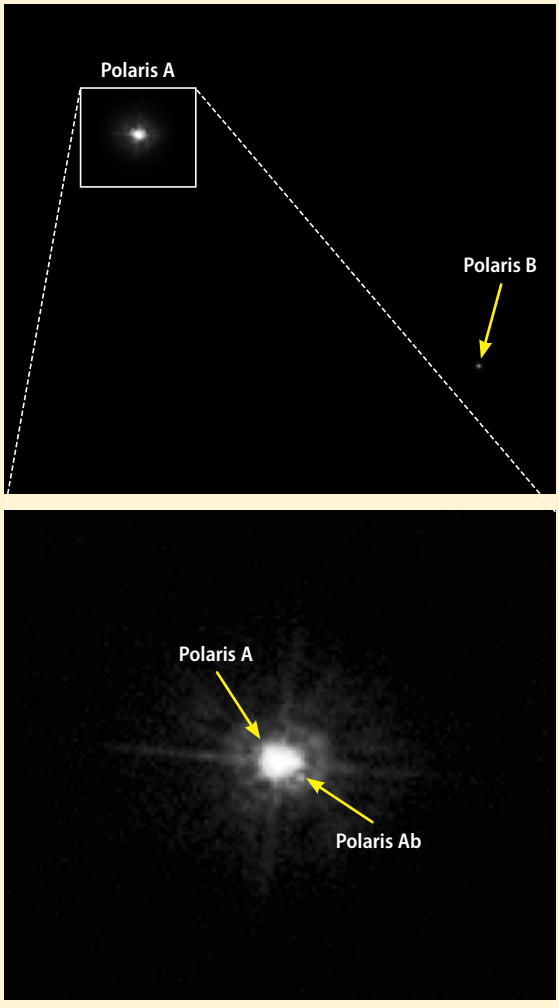
The period-luminosity function itself is an imperfect yardstick that introduces uncertainties. The issue is how to translate a Cepheid's period to an intrinsic brightness and, in turn, use that brightness to estimate the star's distance.

One complicating factor is the dimming effect of interstellar dust on measurements of Cepheid brightness. Unless corrected, errors in the Cepheid distances on the lower rungs can propagate to higher ones — for instance, distance measurements based on supernovae calibrated to Cepheids.

The result of these complications is that Cepheid distances even within the Milky Way are known only to within an "error bar" of 10 percent. That uncertainty has also found its way into cosmological quantities as fundamental as the Hubble constant, which is nothing less than the rate at which the universe is ultimately expanding.

The currently accepted value of the Hubble constant is approximately 72 kilometers per second (km/s) per megaparsec (Mpc). Astronomers use the Mpc unit — equal to 3.26 million light-years — to measure vast cosmological distances. And a Hubble constant of 72 km/s/Mpc means that for every megaparsec a galaxy lies away from us, it appears to recede by an additional 72 km/s, or about 161,000 mph.

But we don't know the precise value for the Hubble constant. Uncertainties in the distance ladder mean that scientists know the rate of cosmic expansion only



The North Star, Polaris, is really a triple star system. By stretching the capabilities of NASA's Hubble Space Telescope to the limit, astronomers captured the first images of Polaris Ab, the nearby companion of the system's main star, Polaris A. Orbiting at a greater distance is the third member of the system, Polaris B. All three stars circle their common center of mass. NASA/ESA/Nancy Evans (Harvard-Smithsonian CfA)/Harold Bond (STScI)

Polaris: the Cepheid next door

Polaris — the famous North Star — is the nearest and brightest example of a classical Cepheid star. Polaris, like other Cepheid variables, pulsates. Over a period of about 4 days, it brightens slightly and then returns to normal. But according to recent research, Polaris is undergoing other changes as well — changes that astronomers don't fully understand.

Astronomers estimate that since the era of Persian astronomer Al Sufi in the late 10th century, Polaris may have changed from magnitude 2.8 to 2.0 on the astronomical brightness scale. That means Polaris more than doubled in brightness in little more than 1,000 years. At least that's the claim of astronomers Scott Engle and Edward Guinan of Villanova University in Pennsylvania.

Engle and Guinan observed Polaris from 2002 to 2004 and measured its brightness. They found it had increased compared to previous observations. Their colleagues were skeptical. "When we first discovered the possible brightening of Polaris back in 2004, it was not openly received," says Engle, a research associate at Villanova currently working on his Ph.D. under Guinan.

Guinan recently visited Iran to pore over Al Sufi's observations in 960 of Polaris. He says that today, the North Star is much brighter than the 3rd- and 4th-magnitude stars that make up nearby members of the Little Dipper. Guinan says that if Polaris had been as bright as it is now (2nd magnitude) during Al Sufi's time, the astronomer would have likely recorded it that way. Instead, he recorded it as a 3rd-magnitude star. (Guinan estimates it was probably close to 2.8 in Al Sufi's time.)

So, what could account for such a rapid rise in the North Star's light output? "My best guess is that Polaris is undergoing rapid internal structural changes," Guinan says, "a rare, very rapid stage of classical Cepheid evolution."

Polaris is shifting in other ways, too. Telescopic observations by Engle and Guinan indicate the difference between Polaris' maximum and minimum brightness — the "amplitude" of its 4-day cycle — is also increasing. "Other astronomers are now confirming our initial finding of the amplitude changes," Engle says. "We have also found previously unrecorded amplitude changes in a number of other Cepheids."

Engle and Guinan were recently granted time on the newly refurbished Hubble Space Telescope to take the most accurate measurements to date of Polaris' brightness. Using Hubble's new Cosmic Origins Spectrograph, they'll also fingerprint Polaris' range of wavelengths. Hopefully the new data will at least confirm the overall brightening of this well-known but not entirely understood star. "It'll be very exciting to see what happens," Engle says. — *B. D.*

to within about 10 percent. This is troubling because a change in the Hubble constant a few percent up or down can affect the outcome of some of the most fundamental cosmological questions. That includes how much nonluminous "dark matter" the universe contains and the very age and fate of the cosmos.

Building a better ladder

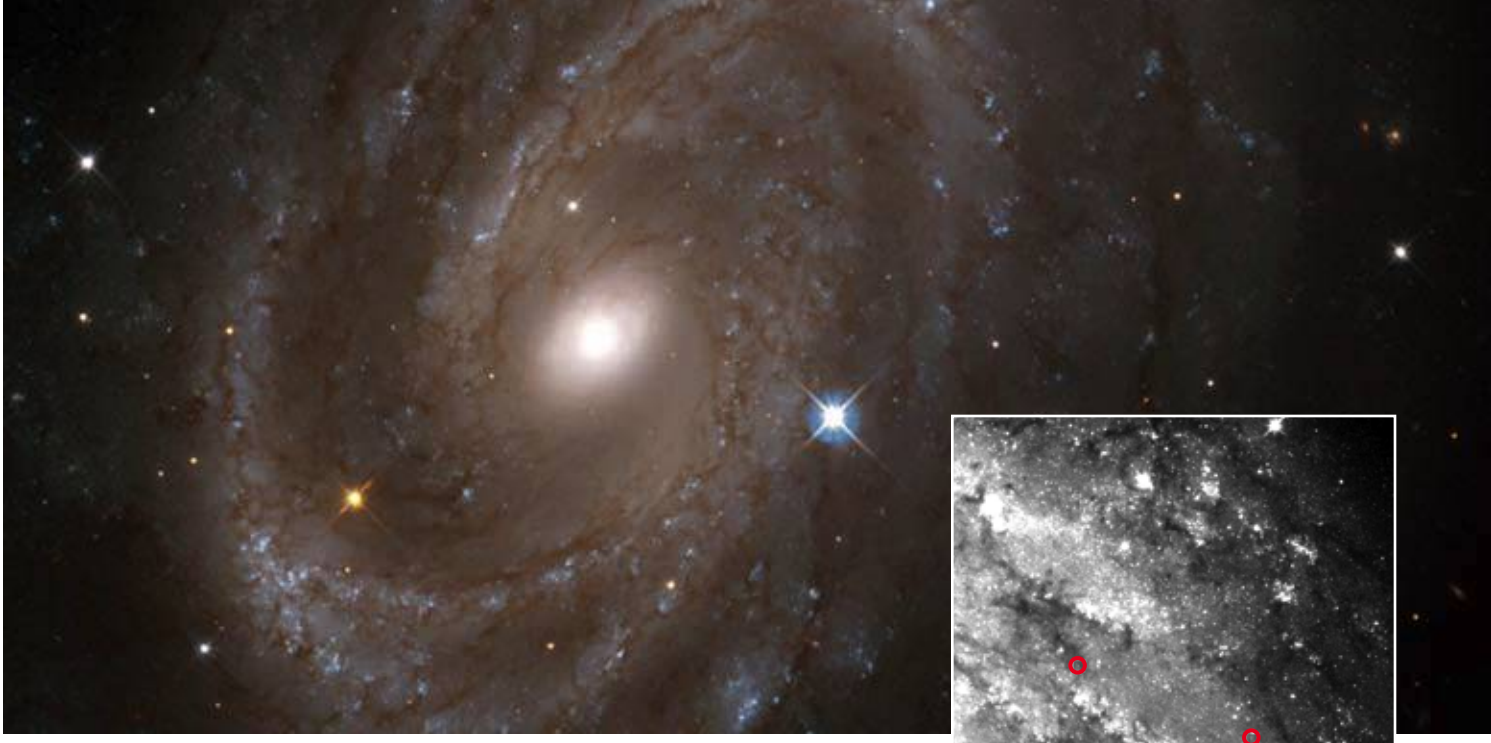
The solution to such key cosmological questions is, as it was in Edwin Hubble's time, better distance measurements. In the 1990s, the Hubble Space Telescope (HST) helped to refine the distance ladder and, ultimately, gave us a more precise estimate of the Hubble constant.

Thanks to the Hubble Key Project on the Extragalactic Distance Scale, astronomers obtained more precise Cepheid distances to a diverse sample of 18 galaxies. Astronomers used the new data to calibrate higher-rung distance estimates.

The HST's 2.4-meter light-gathering mirror was the minimum size astronomers knew they would need to detect far-flung Cepheids in the Virgo cluster of galaxies, which lies on the next farthest rung of the distance ladder from the Milky Way. According to Freedman, the Hubble Key Project's principal investigator, the new Cepheid distances allowed them to shrink the uncertainty in the Hubble constant to 10 percent.

Further improvements have come since then. Adam Riess, an astronomer at the Space Telescope Science Institute in Baltimore, headed a more recent effort using the HST to rebuild the distance ladder. Riess was one of the astronomers who discovered the evidence for dark energy, the mysterious quantity that may drive the accelerating expansion of space.

Riess dubbed his team's effort SH0ES, for "Supernovae, H_0, for the Equation of State of dark energy." (H_0 is the scientific abbreviation for the Hubble constant.) SH0ES has used the HST to observe galaxies with both Cepheids and supernovae in an effort to produce what Riess terms "a simpler distance ladder." By observing



Cepheid variable stars (inset, red circles) sparkle within the spiral galaxy NGC 4603 (above). Astronomers used the Hubble Space Telescope to observe Cepheids in NGC 4603 and other galaxies. The observations improved galactic distance measurements and allowed researchers to make more precise estimates of cosmic expansion. Main image: J. Newman (UC-Berkeley)/NASA; Inset: NASA/ESA/J. Newman (UC-Berkeley)

240 Cepheids in seven galaxies — six of which also harbored supernovae — Riess and his colleagues fixed the Hubble constant at 74.2, plus or minus 3.6. This reduces the uncertainty from 10 percent to 4.8 percent. The new Wide Field Camera 3, installed in May on the HST, should yield additional improvements.

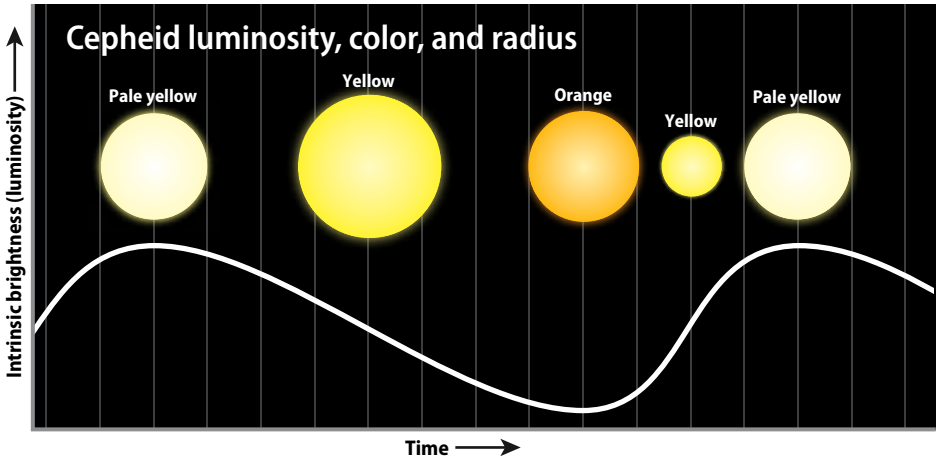
Meanwhile, astronomers are combining light gathered by multiple ground-based telescopes — a technique called interferometry — in hopes of shaving the uncertainty in Cepheid distances to 2 or 3 percent. Then, when Cepheid distances are used to calibrate other techniques, astronomers can approach controversial theories such as dark energy with new confidence. The remaining uncertainty in the Hubble constant is one factor holding cosmologists back from making better measurements of dark energy, Freedman says.

Gaia, the European Space Agency's new satellite for measuring stellar distances that is due for launch in 2011, should also help. The satellite will make direct distance measurements to thousands of Cepheids in the Milky Way.

Also on deck is the James Webb Space Telescope (JWST), slated for launch in 2014. The JWST will observe in the infrared, and that is advantageous for measuring distances. Infrared is less affected by dust along its line of sight (dust can alter measurements of Cepheid brightness).

The new age of infrared astronomy with the JWST should facilitate the detection of heretofore undiscovered Cepheids in more distant galaxies. "Other distance indicators have come and gone," Freedman says, "but Cepheids have been put to increasing levels of scrutiny and have held up for many decades." Now, just as in the early 20th century, progress in understanding the size and fate of the universe will depend in part on Cepheid science.

As for Polaris, within a few million years — after losing its current status as the pole star — it will become a dying stellar remnant. By then, future space explorers may be using what's left of it as an astronomical mile-marker. Its help to Columbus in navigating the oceans on our own planet will long be forgotten, but the legacy of using Cepheids like Polaris to map the cosmos will endure.



As a Cepheid variable star undergoes internal pulsations, its radius and its surface temperature (color) change. Both the radius and the color of the star influence its luminosity and therefore how bright it appears from a distance. However, the relationship between luminosity, temperature, and radius is complex. For example, the star is brightest when it is pale yellow and at its hottest temperature, even though it's not yet at maximum radius.

Learn how to observe Cepheid variable stars at www.Astronomy.com/toc.

Ask Astro

Astronomy's *experts from around the globe answer your cosmic questions.*

Why are galaxies so bright?

Q: What is the center of a galaxy made of that makes it so bright? — **Ev Bruhnke,** Laramie, Wyoming

A: It depends on the galaxy. Many large galaxies contain a central concentration of bright stars. Other galaxies have extremely luminous cores because a central supermassive black hole is consuming matter and radiating energy.

In all galaxies, the density of stars goes up as you move toward the center. Many spiral galaxies have a prominent spherical concentration of stars called a "bulge." The billions of stars crowded together in a large galaxy's bulge make it brighter than the outer portions of the galaxy.

Some galaxy bulges are elliptical in shape. Astronomers suspect bulges develop during the earliest stage of galaxy formation. Other bulges are flatter. These "pseudo-bulges" may form more gradually over time.

A spherical "bulge" of stars illuminates the center of the Sombrero Galaxy (M104) in this visible-light portrait captured by the Hubble Space Telescope. NASA/Hubble Heritage Team (STScI/AURA)

Some galaxies emit enormous amounts of visible light and other radiation from a tiny central region, the nucleus. This light is emitted as gas and stars fall into a central supermassive black hole, containing millions to billions of times the Sun's mass. At times, an active galactic nucleus can outshine the rest of the entire galaxy.

— **Robert Benjamin,** University of Wisconsin-Whitewater

MARTIAN WATER

Q: Could there be large amounts of water in deep aquifers on Mars? — **Jon Kutz,** Lake Crystal, Minnesota

A: There is good circumstantial evidence that abundant underground ice and, possibly, liquid water exist on Mars. For example, impact craters deeper than about 400 yards at the equator and less than 100 yards deep at higher latitudes are surrounded by what looks like formerly muddy debris. Explosive meteorite impacts melted underground ice and splashed out the debris flows, which dried and hardened.

Recent images from the Mars Reconnaissance Orbiter show ice exposed at mid-latitudes in much shallower craters only about 10 yards deep. In 2008, the Phoenix Mars Lander confirmed the existence of ice in the top few inches of the north polar region. And, of course, orbital images have long shown that ice sits on the surface at the frigid poles.

The ice-rich zone on Mars may extend as deep as several miles below the surface. There could be reservoirs of underground water (aquifers) at the base of the ice. The evidence suggests Mars has been volcanically active in recent geological history. Molten rock moving underground could melt subterranean ice and create aquifers.

Once created, however, the aquifers might be short-lived, soon freezing to form ice again. Underground ice deposits would be prime locales to search for chemical evidence of organic processes on ancient Mars, or even remains of microbial life that might have existed at some time in the past. — **William K. Hartmann,** Planetary Science Institute, Tucson, Arizona

ASTRO-HISTORY

Q: Who was the first person in history to accurately predict a solar eclipse? — **Hunt Hodgetts,** Atlanta

A: The ancient Greek astronomer Thales of Miletus (ca. 624 B.C.–ca. 546 B.C.) was the first person alleged to have predicted the date of a solar eclipse. According to the Greek historian Herodotus, Thales predicted a solar eclipse for the year 585 B.C. Thales may have used Babylonian astronomical records to make his prediction.

The eclipse occurred May 28 and stopped a great battle. However, some historians and astronomers doubt Thales could have actually made such an accurate prediction.

The Moon has a complicated orbit that repeats every 18 years, 11 days, and 8 hours. This "Saros cycle" makes it possible to predict dates of future eclipses. The more challenging problem is determining the path of the Moon's shadow during a solar eclipse. To see a total eclipse, an observer must stand within the shadow's path, which is at most 200 miles (320 kilometers) wide.

In 1715, astronomer Sir Edmond Halley used Isaac Newton's law of gravity to make the first accurate prediction of a solar eclipse. He also published a now-famous map of the eclipse's path of totality.

Halley independently calculated the Moon's Saros cycle and applied Newton's work to describe the Moon's motion and position in great detail. This was difficult work. Newton is reported to have said that predicting the Moon's position was the only thing that gave him a headache.

Today we use a refined version of Halley's work to predict these events. The honor for the prediction of solar eclipses should go to Edmond Halley rather than Thales. — **Raymond Shubinski,** Contributing Editor

SUPERNOVA SCIENCE

Q: Could the nearby star Sirius B explode as a type Ia supernova, like some other white dwarf stars in binary star systems have? — **Bruce Mason,** Encinitas, California

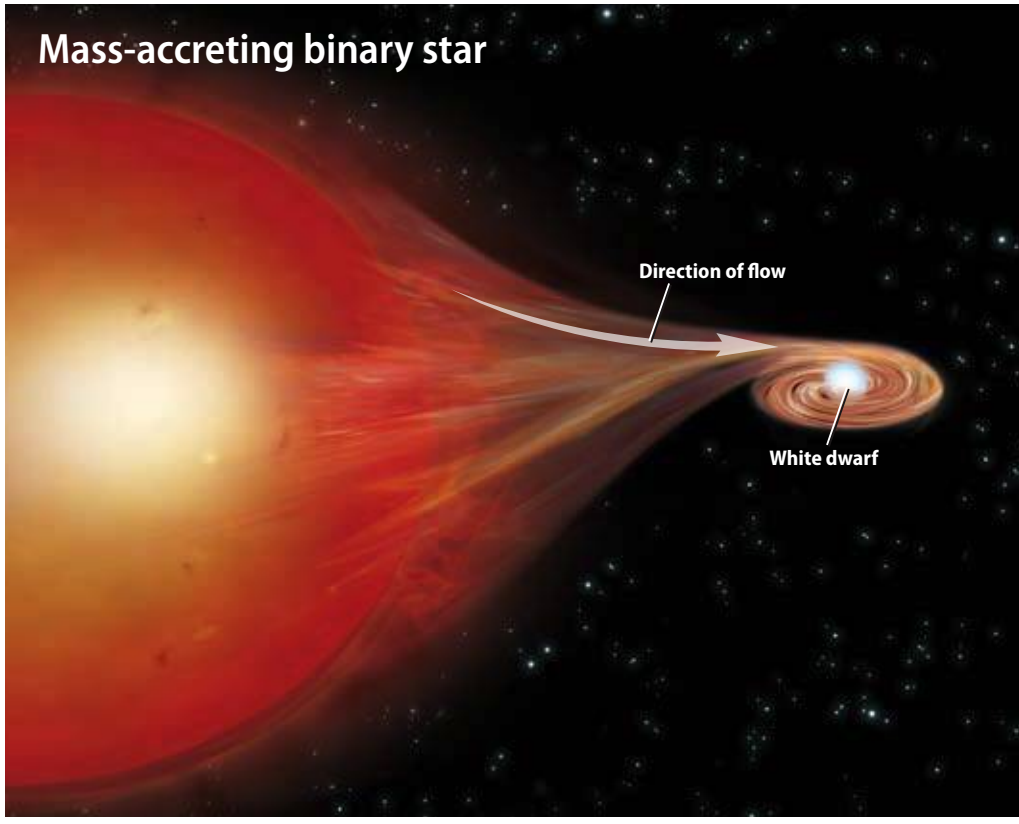
A: A type Ia supernova occurs when a white dwarf — the cooling remnant of an aging star — draws hydrogen from a companion sun. When the dwarf reaches 1.4 times the mass of the Sun, the star spontaneously detonates in a fantastically bright thermonuclear blast. Nothing remains of the dwarf except debris.

The Sirius system, about 8.6 light-years from us, does include a white dwarf star (Sirius B) orbiting a companion (Sirius A). However, **Sirius B is not close enough to its companion to accrete hydrogen and reach the supernova threshold of 1.4 solar masses.**

Sirius B takes roughly 50 years to orbit Sirius A. At their nearest approach, the stars are still some 7 astronomical units from each other, or 7 times the Earth-Sun distance. The separation is too wide for mass to cross between Sirius A and Sirius B.

For mass transfer to occur, the two stars would need to be within a few stellar radii of each other. At that distance, they would complete an orbit over a period of hours to days. — **Liz Kruesi,** Associate Editor

What is the nearest star to the Sun? Find out at www.Astronomy.com/toc.



A type Ia supernova occurs when a white dwarf star draws mass from a close companion star. When the dwarf's mass exceeds a critical threshold, it collapses and explodes in a thermonuclear detonation. For mass to transfer, the gap between the stars must be relatively narrow. *Astronomy:* Roen Kelly

GAS ATTACK

Q: The surface of Neptune's moon Triton is partially made up of methane. If an asteroid were to collide with it, would that touch off an explosion? — **Harvey Roberts, Jr.,** Kansas City, Missouri

A: With no oxygen available in Triton's atmosphere to fuel ignition, the methane on the surface cannot explode.

The temperature on Triton's surface is –391° Fahrenheit (–235° Celsius). This means even gases are frozen like rock on Triton's surface. It consists chiefly of frozen nitrogen, water ice, and frozen carbon dioxide ("dry ice"). A relatively small amount of methane exists on Triton (about 0.1 percent).

Saturn's moon Titan, however, appears to possess abundant methane in the form of liquid hydrocarbon seas near its poles. The heat of a meteorite impact would vaporize the liquid into gas, but without oxygen in the atmosphere, the methane could not burn.

The explosion of the impact would be enough to create quakes and launch debris in a wide zone around the crater, but methane on either Triton or Titan is not in danger of igniting. — **Paul Schenk,** Lunar and Planetary Institute, Houston

Send your questions via e-mail to: **askastro@astronomy.com**; or write to **Ask Astro, P. O. Box 1612, Waukesha, WI, 53187.** Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

Astrophotography special

Astronomy's 2009 Astroimaging

Amateurs accepted the challenge and sent us these dazzling images. **by Michael E. Bakich**

The world's best astroimagers contribute to *Astronomy*. Because so many sent in terrific images, they made judging the 2009 *Astronomy* Astroimaging Contest difficult.

Our Grand Prize winner, Tony Hallas of Foresthill, California, receives a 5-night stay at Arizona Sky Village in Portal, Arizona, or Rancho Hidalgo Astronomy Village in Animas, New Mexico (worth $3,500) plus $1,000 to cover airfare, rental car, and food. You can ogle his Andromeda Galaxy (M31) shot on the next two pages.

The winner in our Deep-Sky category is Rogelio Bernal Andreo of Sunnyvale, California. He created a wide-field view of many classic celestial objects in Orion. Andreo wins a set of 4 nebula filters (Deep-Sky, UHC, OIII, and Hydrogen-Beta) from Lumicon worth $400.

In the Solar System category, Damian Peach of Buckinghamshire, England, came out on top with an amazing high-resolution image of Jupiter and two of its large moons. A mounted 1¼" Hydrogen-alpha filter from Astrodon Filters worth $275 will head his way soon.

And in our General category, Anthony Ayiomamitis of Athens, Greece, captured the Moon rising behind an ancient Greek temple. He wins a 13mm Ethos eyepiece from Tele Vue Optics worth $620.

All the images you'll see in this section were official contest entries. In addition, subscribers can view every contest submission we received by visiting our web site at www.Astronomy.com/contest.

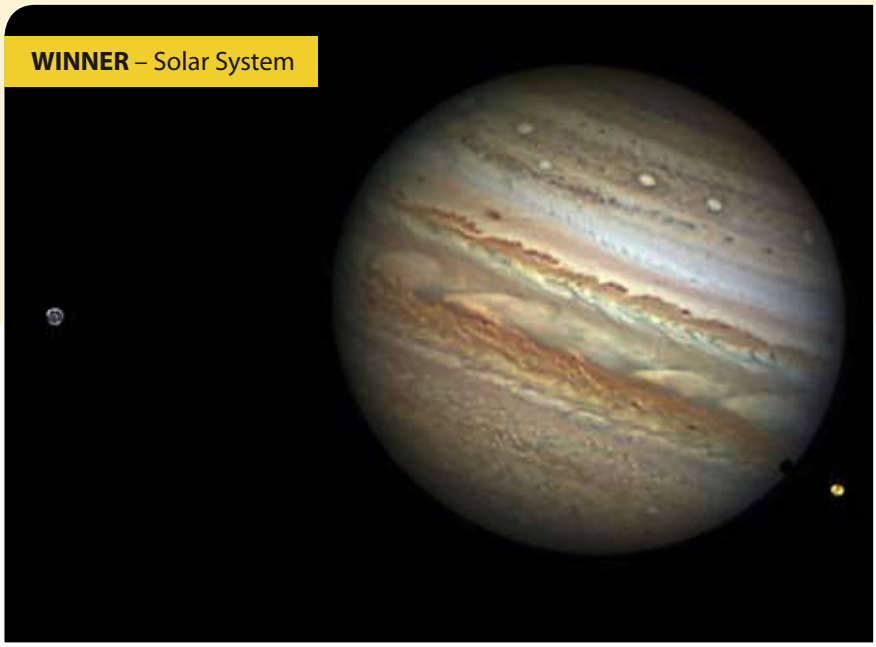
Michael E. Bakich *is a senior editor of* Astronomy. *Send him your astrophotos at ReaderGallery@Astronomy.com.*

WINNER – General

The Full Moon rises over the Temple of Poseidon in Sounion, Greece. The imager's main task was to identify the time that would yield the right balance between the Moon and the natural lighting of the temple. That turned out to be 22 minutes after sunset. He then spent several months calculating the perspective sizes of the two objects. Finally, he identified which Full Moon rose closest to the temple. (4-inch Takahashi FSQ-106 refractor at f/5, Canon EOS 300D DSLR, ISO 400, 0.1-second exposure taken June 18, 2008, at 18h25m02s UT) • Anthony Ayiomamitis, Athens, Greece

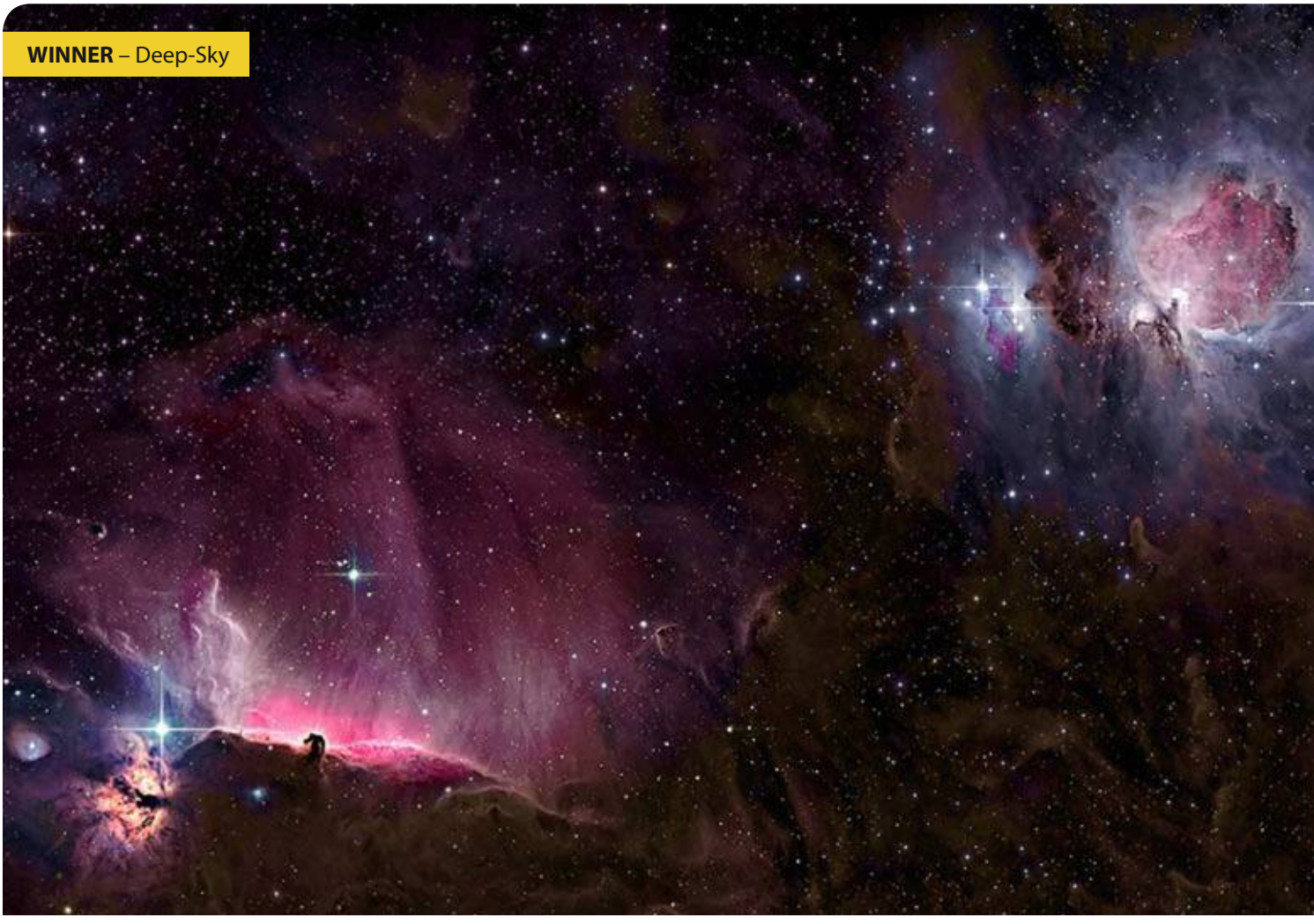
Contest

WINNER – Solar System



Jupiter and its satellites Ganymede (left) and Io show lots of detail in this composite image. The photographer took a brief movie through red, green, and blue filters and selected about 1,000 frames from each color to combine to form the final image. To the lower right, orange Io casts its shadow onto Jupiter's cloud tops. (14-inch Celestron Schmidt-Cassegrain telescope at f/10, Lumenera SKYnyx 2.0M CCD camera, RGB image with approximately 1,000 frames per filter averaged, taken May 27, 2007, at 5h31m UT) • Damian Peach, Buckinghamshire, England

WINNER – Deep-Sky



This wide-field view takes in a vast array of nebulosity in the constellation Orion the Hunter. It includes the Orion Nebula (M42) at upper right, the Running Man Nebula (NGC 1973–5–7) to the left of M42, the Flame Nebula (IC 434) at lower left, and the Horsehead Nebula (B33), which sits to the right of the Flame Nebula. (4-inch Takahashi FSQ 106 EDX apochromatic refractor with 0.7x reducer [f/3.6], SBIG STL-11000 CCD camera, HαLRGB image with exposures of 240, 167, 40, 10, and 120 minutes, respectively) • Rogelio Bernal Andreo, Sunnyvale, California

SPECIAL SECTION: Astroimaging Contest

GRAND PRIZE WINNER

The Andromeda Galaxy (M31) is the sky's brightest spiral galaxy. To create this image, astrophotographer Tony Hallas made 10 vertical panels through a 14.5-inch telescope and nine horizontal "background" panels through a 6-inch Stellarvue telescope. Each vertical panel combined seven 25-minute exposures through L, R, G, and B filters; the horizontal panels combined five or six 20-minute exposures through L, R, G, and B filters. The total exposure time thus equaled approximately 19 hours, and the entire project (including image processing) took 4 months. (14.5-inch RC Optical Systems Classical Cassegrain Carbon Tube Telescope at f/8 paired with a Santa Barbara Instrument Group [SBIG] STL-11000 CCD camera, 6-inch Stellarvue refractor at f/7.9 with an SBIG ST-10E CCD camera, Astrodon filters, Astro-Physics 1200GTO German equatorial mount)
• Tony Hallas, Foresthill, California

10 tips for beginning astroimagers

As you page through this special astroimaging section, some of you might think, "I wish I could take pictures like that." Well, with the right equipment, a little information, and practice, you can.

As *Astronomy*'s photo editor, I receive hundreds of new astroimages each month. One of the most exciting aspects of my job is that I've seen how certain astroimagers' work has improved. And although I do not image celestial objects, I've learned a lot about producing great images from the world's best astrophotographers. In this article, I'll share 10 quick tips specifically for those of you just starting out.

1 Invest in a high-quality mount

Think of a telescope as having three main parts: the optical tube assembly, the mount (also called the drive), and the base. Every observer wants top-notch optics, and today's telescopes have the best ever. Likewise, the base — whether it's a tripod or a permanent pier — has to be stable (and most are). Any wobble here just won't do.

Sitting between the optics and the base is the mount, and that's where some systems come up short. Imagers usually choose equatorial mounts. You can use an alt-azimuth mount to image, but because the field of view rotates as an alt-azimuth drive moves, you must add an additional component called a field derotator. Whichever mount you pick, be sure it's accurate and can carry the load you'll put on it.

2 Steer clear of bad vibes

A high-quality imaging system won't produce a good image if you haven't protected it from vibrations. Traffic on a nearby street can introduce vibrations, but so can footsteps around the telescope, focusing, or camera shutters. Remember, you're striving for arcsecond accuracy.

Sometimes, adding anti-vibration pads under your tripod's legs will fix the problem. Another method is to attach weight to each leg. Adding mass gives the tripod stability and makes it less prone to flexure.

3 Focus, focus, focus!

No matter how much money you spend on your equipment or how much time you devote to imaging and post-processing, if your focus is off, your image will suffer. Visual observers refocus every time they move the telescope. Admittedly, it's not as easy to refocus a CCD or digital camera attached to a telescope as it is to turn a knob while you're looking through an eyepiece, but it must be done.

And keep in mind that telescope focus depends on temperature. As the night cools down (or as the day warms up if you're imaging the Sun), you must refocus to compensate.

4 The all-important f-number

For imaging deep-sky objects, your telescope's f-number (its focal ratio) is important. The focal ratio determines how much light the detector picks up in a given amount of time. If you want to take short exposures of nebulae or galaxies, you need a fast focal ratio. The lower your telescope's f-number, the faster it will gather light during a given exposure.

If you want more stars on your image, you'll need a larger telescope. Larger apertures brighten pinpoint sources.

Big telescopes offer another plus for imagers: Objects appear larger through a scope with a longer focal length. An 8-inch f/8 telescope (focal length = 1,626 millimeters) produces an image twice as large as a 4-inch f/8 scope (focal length = 813mm).

So, here's a tip: A 4-inch f/8 telescope has the same focal length as an 8-inch f/4 telescope. The image scale is the same, but pick the larger scope because it's 4 times faster.

5 Love the signal, hate the noise

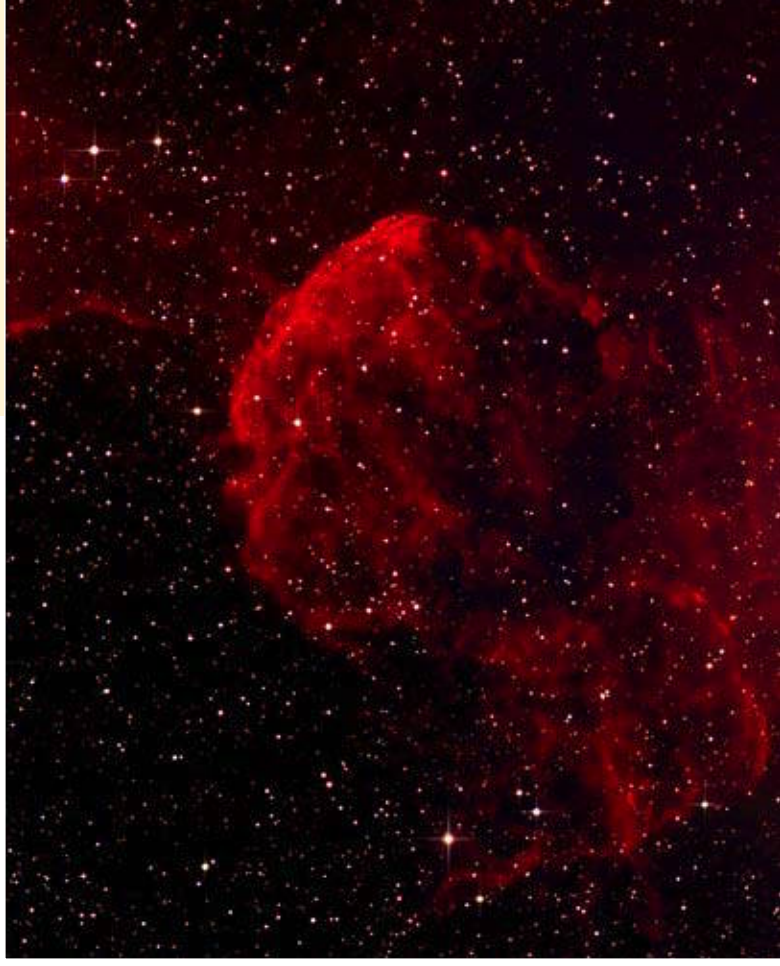
Imaging galaxies from a city can prove difficult. Light-pollution filters don't work for them because galaxies emit light across the visible spectrum. To compensate, boost the signal-to-noise ratio.

In this case, the "signal" is the galaxy, and the light pollution is the "noise." And although the noise is large, you must accurately subtract it from the overall light to produce a high-quality image. To maximize the galaxy's light and minimize the contribution from light pollution, take longer exposures.

Another way to improve your image's signal-to-noise ratio is to use a fast focal ratio. Remember, an f/4 system accumulates a signal 4 times faster than an f/8 system. Many imagers use a focal reducer. For example, most Schmidt-Cassegrain telescopes have an f/10 focal ratio. However, manufacturers sell reducers that drop the focal ratio to f/6.3. This provides a 2.5x increase in speed and a nice boost to your image's signal-to-noise ratio.

6 Stack the deck in your favor

Many imagers deal with telescope mounts whose drives don't track the sky precisely enough to allow long exposures. To offset this problem, take short exposures and use software to stack them to create the final image. Stacking the best images removes the effects of atmospheric seeing and improves the signal-to-noise ratio.



The Jellyfish Nebula (IC 443) is a supernova remnant in the Milky Way. The star that created it exploded about 8,000 years ago. As the expanding material interacts with interstellar hydrogen, new stars will ignite. (4-inch Tele Vue NP-101 refractor at f/5.4, SBIG ST-10XE CCD camera, HαRGB image with exposures of 210, 50, 50, and 50 minutes, respectively) • Ted Wolfe, Naples, Florida

If you're stacking a few images, you can use a program like Adobe's *Photoshop*. Some imagers stack many exposures — sometimes more than 100. In those cases, programs like *Astrostack* and *RegiStax* work well. Each comes with a tutorial.

7 How's the weather?

You may know if tonight will be clear or cloudy, but do you know tonight's scattering potential? The amount of light pollution at your site varies depending on weather conditions. And, apart from direct lights shining on your scope, light pollution's main component is scattered light. So, image on nights when scattered light is at a minimum.

Besides air, pollution, water vapor, and dust scatter light. But certain weather minimizes scattering. For example, wind and rain frequently accompany a cold front. Both can reduce dust and pollution, so the air is cleaner after a cold front passes. The amount of water vapor also drops because cold air holds less moisture than warm air.

Also, it's not just earthbound fixtures that contribute to scattered light. The Moon creates a bright problem if there's a lot of dust or moisture aloft. So watch the weather, and take advantage of nights that have a low scattering potential.

8 Consider an observatory

Many imagers set up and align their systems every time they use them. If this approach seems daunting to you, a backyard observatory can save you a lot of time. Because your system stays outdoors, it's always at the right temperature and polar aligned. In addition, you won't have to lug a tube, mount, tripod, counterweights, and accessories anywhere. You'll also reclaim any storage space in your house.

If you decide to build an observatory, start with an overall plan. Will you have one telescope or more? If you live in a cold climate, do you need a warm room? Should you run data lines from your house for a computer hookup? Will the facility have a dome or a roll-off roof? Answer these questions, use high-quality materials, and your observatory will be a joy to use for years. (See "How to build a backyard observatory" in the March 2009 issue of *Astronomy*.)

9 Learn from the experts

In addition to reading all you can about general photographic techniques, find out how longtime imagers acquire and process their data. A good place to start is by reading the captions in this special section or in *Astronomy*'s monthly "Reader Gallery." Make adjustments that take into account how your equipment differs from the imagers credited in the captions. Then try their ISO settings, filter combinations, and exposure times. Check your results, and make any adjustments you think would improve the image.

Electronic social networking also is valuable for all imagers, not just new ones. One popular site is Astronomy.com's "Astro Imaging" forum section at www.Astronomy.com/forums.

Dedicated amateur astronomers also have set up other Internet groups for like-minded photographers. You'll find groups for solar, lunar, planetary, and deep-sky imaging. When you join one, don't be afraid to ask questions.

10 Shoot what makes you happy

As you embark on your imaging, you'll naturally begin by shooting the same objects that appear in *Astronomy* or elsewhere. As you refine your techniques, however, certain objects or types of objects will interest you more than others. Target those. The more you concentrate on one type of object, the better your images will be.

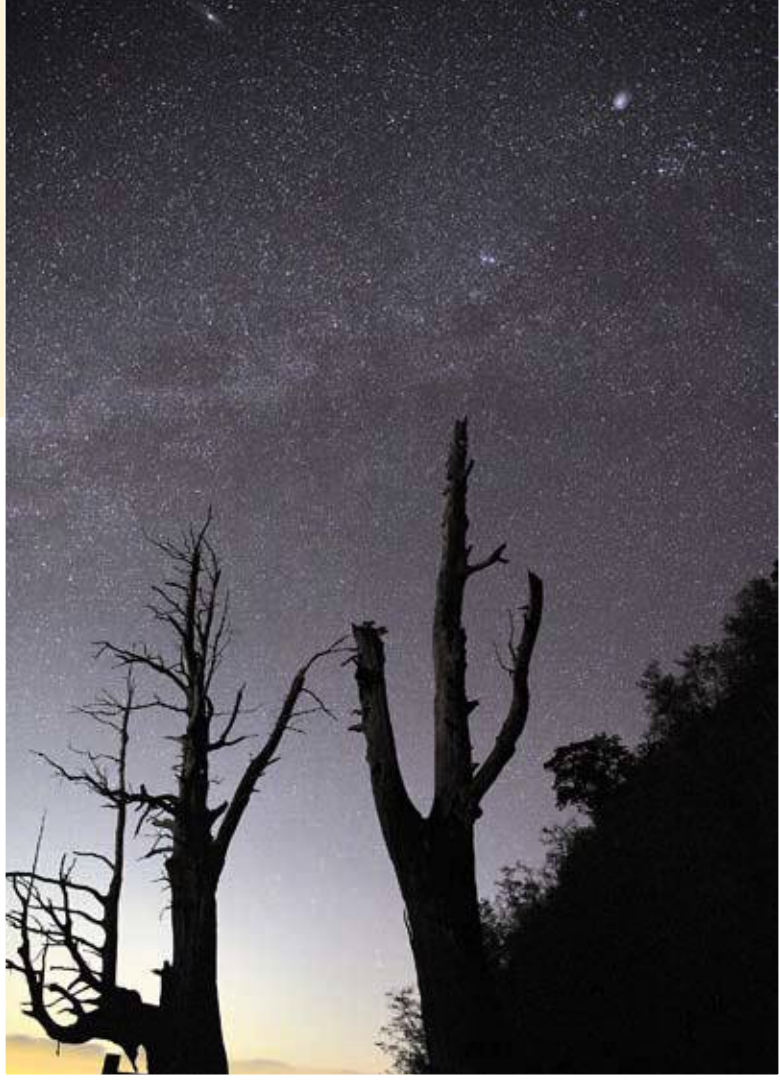
Try to remain flexible in what you shoot. Don't pass up imaging a new comet, planetary conjunction, or solar eclipse just because your "specialty" lies elsewhere. And, remember, whatever images you create, send them to me here at the magazine.

Go make pretty pictures

Taking skyshots doesn't have to be complicated. You can start with a simple camera on a tripod. As you advance, your results will improve. Upgrade your equipment when you can, but stay within your budget. By all means, at each stage along your photographic odyssey, have fun.

Star trails combine with an aurora in this image taken at Chiefland Astronomy Village, Florida. A large solar flare several days earlier had produced aurorae seen throughout North America. The camera picked up the pink glow from the northern lights that was not visible to the naked eye. (Canon F-1 camera, Canon 24mm lens at f/5.4, Kodak 100 ASA film, 3-hour exposure started at 9 P.M. EST November 21, 2003) • J. Allen Como, Stuart, Florida

The space shuttle Endeavor (STS-123) stands on the pad minutes before a night launch March 11, 2008. The mission delivered the Japan Aerospace Exploration Agency's module to the International Space Station. (Sony Alpha-100 digital SLR, 80mm lens at f/5.6, ISO 400, 13-second exposure) • Scott Robertson, Long Beach, California

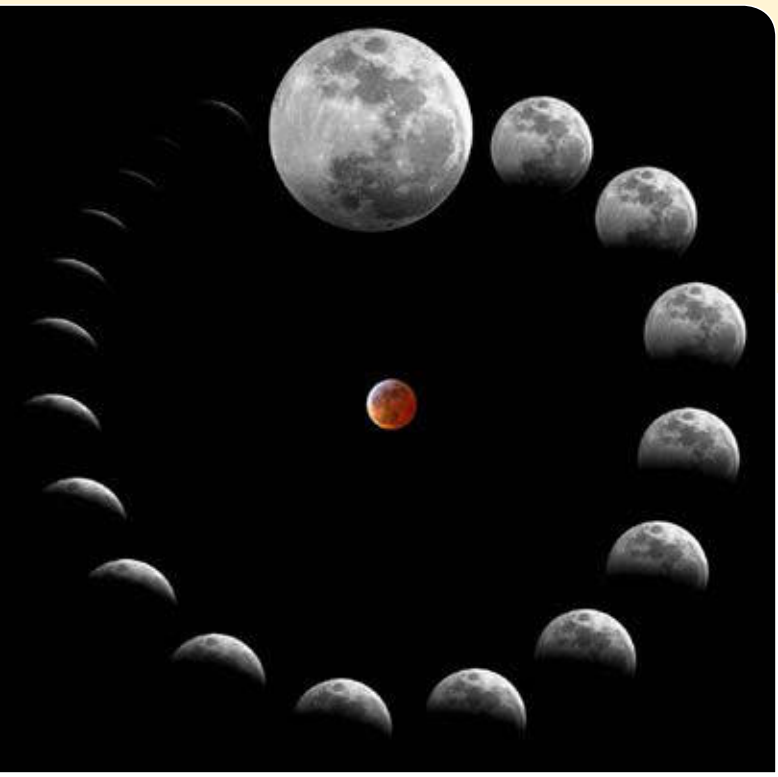


The Couples' Tree, a famous pair of trees in Taipei, Taiwan, stands under a star-filled sky featuring Comet 17P/Holmes to the upper right and the Andromeda Galaxy (M31) to the upper left. At the time of this photograph, the two sky objects were 25° apart. (Canon EOS 5D digital SLR, Canon EF 24mm f/1.4 lens at f/2.8, ISO 1600, 20-second exposure taken December 14, 2007, at 8:38:24 P.M. local time) • Li-Chun Chen, Taipei, Taiwan

Spiral galaxy NGC 6951 lies 110 million light-years away in the constellation Cepheus. Astronomers classify NGC 6951 as a Seyfert galaxy. Such an object has a bright nucleus and lots of highly ionized gas. (16-inch RC Optical Systems Ritchey-Chrétien telescope at f/9, SBIG ST-10XME CCD camera, LRGB image with exposures of 10, 5, 12, and 15 minutes, respectively) • image by Warren A. Keller, Buckhannon, West Virginia; processing by Martin Winder, Linz, Austria

The Moon and Venus shone above the Madrid, Spain, skyline in January. Each object was bright enough to overcome clouds and light pollution. At the time of this photograph, the two objects were about 7° apart. (Canon EOS 5D Mark II digital SLR, EF 16-35mm f/2.8 lens set at 28mm and f/5.6, ISO 400, 8-second exposure taken January 29, 2009, at 18h54m55s UT) • Paul Veronese, Madrid

Face-on spiral galaxy NGC 3184 in Ursa Major lies 0.75° west of magnitude 3.0 Mu (μ) Ursae Majoris. The galaxy spans 50,000 light-years and lies 25 million light-years away. (14-inch Celestron CGE-14 Schmidt-Cassegrain telescope at f/10, Starlight Xpress MX916 CCD camera, LRGB image with exposures of 170, 50, 30, and 40 minutes, respectively) • Al Kelly, Friendswood, Texas



^A heavily cratered region lies at the Moon's south pole. Observing this area is difficult because some parts are constantly hidden behind hills and crater walls. (12-inch Gladio 315 Lazzarotti Optics telescope at f/25, Lumenera Infinity 2-1M CCD camera, best 260 of 2,000 frames, each a 0.055-second exposure, taken April 4, 2006, at 18h41m UT)
• Paolo Lazzarotti, Massa, Italy

<This lunar eclipse occurred March 3, 2007. The photographer took multiple exposures from the start of the eclipse until Earth's shadow totally engulfed the Moon. He then compiled the individual shots into this mosaic. (3.6-inch Meade ETX-90ec Schmidt-Cassegrain telescope at f/13.8, HP Photosmart 850 digital camera, taken March 3, 2007, at 23h45m local time)
• Miguel Claro, Almada, Portugal

The Eta Carinae Nebula (NGC 3372) sits in the southern constellation Carina the Keel. Although it is brighter and four times larger than the Orion Nebula (M42), its southern location ensures it is not as well-known. (10-inch Takahashi BRC-250 Baker-Ritchey-Chrétien reflector at f/5, SBIG STL-11000XMC CCD camera, one hundred sixty 15-minute exposures, stacked) • Ryan M. Hannahoe, Bozeman, Montana

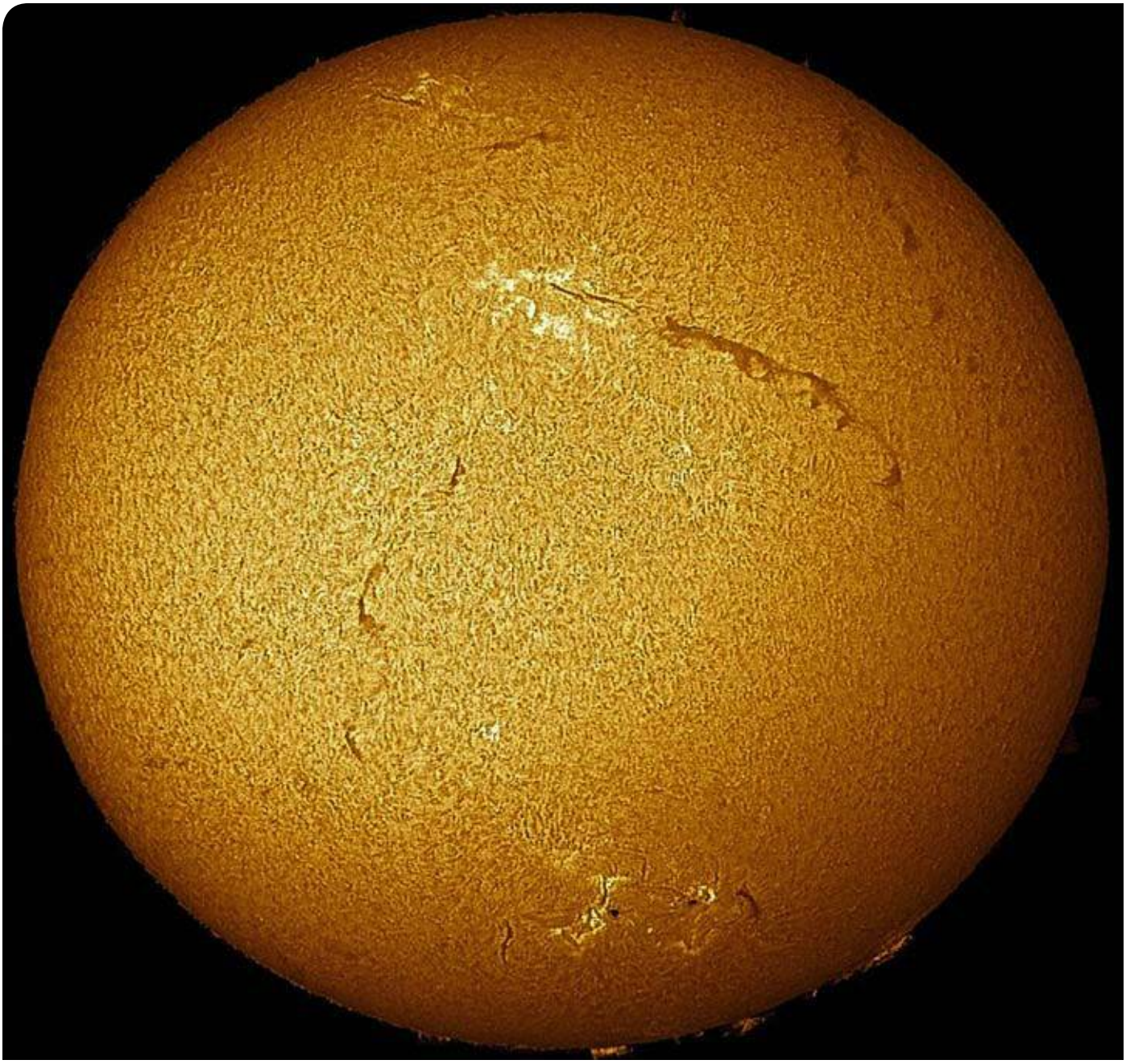
The Baby Nebula (IC 1848) is an emission nebula in Cassiopeia. When the imager used software to map the data as an RGB image, he assigned Sulfur-II to the red channel, Hydrogen-alpha to the green, and Oxygen-III to the blue. (4-inch Takahashi FSQ-106 refractor at f/5, SBIG ST-10XME CCD camera, Hα/SII/OIII image with exposures of 4, 2, and 2 hours, respectively) • Don Taylor, Conroe, Texas

The Frost Moon is one of the names given to the Full Moon of November. With image-processing software, the photographer enhanced the Moon's color to show different mineral deposits on the lunar surface. (5-inch Celestron spotting scope, Canon Rebel 300D digital SLR, ISO 400, 1/500-second exposure, taken November 12, 2008, at 10:41:16 P.M. CST) • Steve Engleman, Richardson, Texas

Our last contest entry — received 15 minutes before the deadline — shows the colorful panorama of the Running Man Nebula (NGC 1973–5–7). This object sits approximately 0.5° due north of the Orion Nebula. (8-inch Takahashi MT-200 Newtonian reflector at f/4.5, SBIG ST-10XME CCD camera, LRGB image with exposures of 60, 40, 40, and 40 minutes, respectively) • Daniel B. Phillips, Oceanside, California

The Whirlpool Galaxy (M51) is one of the sky's most famous celestial wonders. Charles Messier discovered it in 1773, and Pierre Méchain discovered the Whirlpool's smaller companion, NGC 5195, in 1781. (14.5-inch RC Optical Systems Ritchey-Chrétien telescope at f/9, SBIG ST-10XME CCD camera, LRGB image with exposures of 120, 30, 30, and 30 minutes, respectively) • Randy Brewer, Redondo Beach, California

The Sun through a Hydrogen-alpha (Hα) filter displays white flares, black sunspots, and mottling on its surface. In addition, prominences in a variety of shapes arc above its limb. (4-inch Tele Vue TV-102 refractor, Coronado SolarMax 90 0.7-Angstrom Hα filter, SBIG ST-2000XM CCD camera, 0.008-second exposure, taken April 5, 2009) • Greg Piepol, Rockville, Maryland



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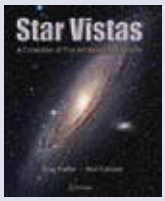
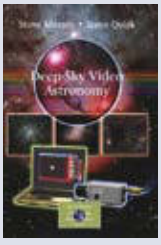


Star Vistas
A Collection of Fine Art Astrophotography
by Greg Paker and Noel Carboni
2009, 158 p., 95 illus.19 in color; Hardcover
ISBN: 978-0-387-88435-6 Price: **$39.95**

Star Vistas contains some of the most exquisite star and constellation photographs ever made using commercially available amateur equipment and software! Whether used as a reference for amateur imaging or simply as a book of beautiful images, this work deserves a place in the library of anyone interested in our universe. Contains forewords by the late Sir Arthur C. Clarke, Sir Patrick Moore, and Dr. Brian May, all admitted admirers of Greg Parker's work!

Shrouds of the Night
Masks of the Milky Way and Our Awesome New View of Galaxies
by David Block and Kenneth C. Freeman
2009, 436 p., 204 illus., 20 in color; Hardcover
ISBN: 978-0-387-78974-3 Price: **$39.95**

Galaxies are encased within shrouds, or veils, of cosmic dust. With the advent of near-infrared technology, astronomers have been able to pierce the veil of these dust shrouds. In this book, the reader is taken to the cutting edge of our knowledge about galaxies and shown pioneering astronomical photographs available to the public for the first time, and contains historical material never before published from the Lowell Observatory in Arizona and the archives of the Royal Astronomical Society.



Deep-Sky Video Astronomy
Series: Patrick Moore's Practical Astronomy Series
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2009, 185 p., 52 illus., 34 in color; Softcover
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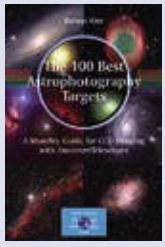
Need a concise guide to using modern video cameras for amateur deep-sky viewing and imaging? Here it is! In this book, you are given the basics of this highly efficient technology, which now competes with CCD cameras in quality and ease of use. Much of the book focuses on the practical side of creating beautiful and detailed astronomical portraits using image-stacking software and picture enhancement tools. There are sections on how to create color images using a black-and-white camera and also reviews of useful accessories.



The 100 Best Targets for Astrophotography
A Monthly Guide to CCD Imaging with Amateur Telescopes
Series: Patrick Moore's Practical Astronomy Series
by Ruben Kier
2009, 250 p., 115 illus. in color; Softcover
ISBN: 978-1-4419-0602-1 Price: **$34.95**

Any amateur astronomer who is interested in astrophotography, particularly if just getting started, needs to know what objects are best for imaging in each month of the year. These are not necessesarily the same objects that are the most spectacular or intriguing visually. This book reveals the choicest celestial treasures within the reach of a commercial CCD camera.

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Secret Sky

by Stephen James O'Meara

Readers report 2009

From ice crystals to a cluster's heart, I've read about some interesting observations.

Once again, thank you to everyone who has e-mailed me with observations. I've enjoyed reading them all and plan to devote future columns to some of the topics. Until then, I'd like to share with you a few interesting reader reports.

Daytime Jupiter

In the May 2007 issue, I discussed some historical naked-eye sightings of Venus in the daytime. This inspired Stephen Bedingfield of Yellowknife, Northwest Territories, to spend a few days looking. "Finally," he says, "I had a positive observation on May 3, 2007."

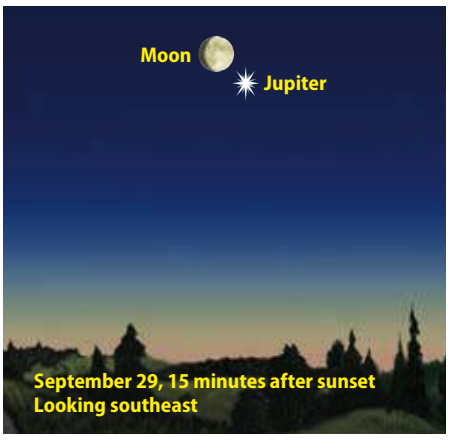
However, Bedingfield had an even more interesting experience October 14, 2007, while driving south down a road in his hometown. Suddenly, at 5:35 P.M., he spotted a "silvery, steady apparition" in the sky about 5° above the horizon and framed by some buildings. The Sun was 55° to the west, hidden behind buildings, and about 50 minutes from setting.

Bedingfield knew the object couldn't have been Venus because it would have been just setting some 40° west of the Sun. "I stopped my vehicle to observe for any motion," he recalls, "because I thought it might be an Iridium flare" (sunlight reflecting off a satellite). But the object didn't move. A later check for Iridium satellite passes over his area at that time also turned up negative.

What did Bedingfield see?

Jupiter shining at magnitude –1.9! "It was a beautiful sighting," Bedingfield says, "and the first time I have seen Jupiter in daylight."

In 2009, Jupiter reaches opposition on the night of August 14/15, when it will rise as a magnitude –2.9 star just as the Sun sets. During September, however, the planet will be visible above the southeastern horizon shortly before the Sun sets. What's more, on September 29 at 8 P.M. EDT, a waxing gibbous Moon will pass 3° north of magnitude –2.7 Jupiter. So you can use the Moon as a guide to Jupiter before the Sun sets about 1½ hours earlier. First find the planet through your binoculars. Then try to see it with your unaided eyes. Let me know if you succeed. You can also e-mail Bedingfield at stephen@SkyRiver.ca.



In late September Jupiter will shine at magnitude –2.7 — bright enough to observe before the Sun sets. On September 29 the Moon will pass 3° north of Jupiter. *Astronomy*: Roen Kelly

Crystal palace at night

In the January 2008 issue, I described some unusual daytime sky phenomena.

Specifically, the article focused on two rare ice-crystal displays: (1) the circumhorizon (or circumhorizontal) arc, which develops as sunlight enters the vertical sides of hexagonal (six-sided) plate crystals and exits through their horizontal lower faces; and (2) the infralateral arc, which forms when sunlight passes between the sides and ends of pencil-shaped (hexagonal column) crystals.

At certain solar elevations, both phenomena can appear essentially in the same location! They can also look the same, each appearing as a wide, colorful band with a base that parallels the horizon about 46° from the Sun. The infralateral arc curves upward slightly at its ends, but the two are hard to tell apart.

Tunç Tezel captured this arc display in 2005. Ice crystals had to align just right in the atmosphere while the Full Moon sat at 65° altitude. Tunç Tezel

After reading about these phenomena, Tunç Tezel of Bursa, Turkey, rifled through some old photographs he had taken of an ice crystal display December 13, 2005 — one created by light from a nearly Full Moon.

His image shows a brilliant halo around the Moon with a radius of 22°. Because Mars was conveniently located 22° away from the Moon at the time, it lay inside the halo, to the lower right.

But Tezel was more interested in the fainter and more colorful arc between the base of the 22° halo and the horizon. When he took the photo, the Moon had

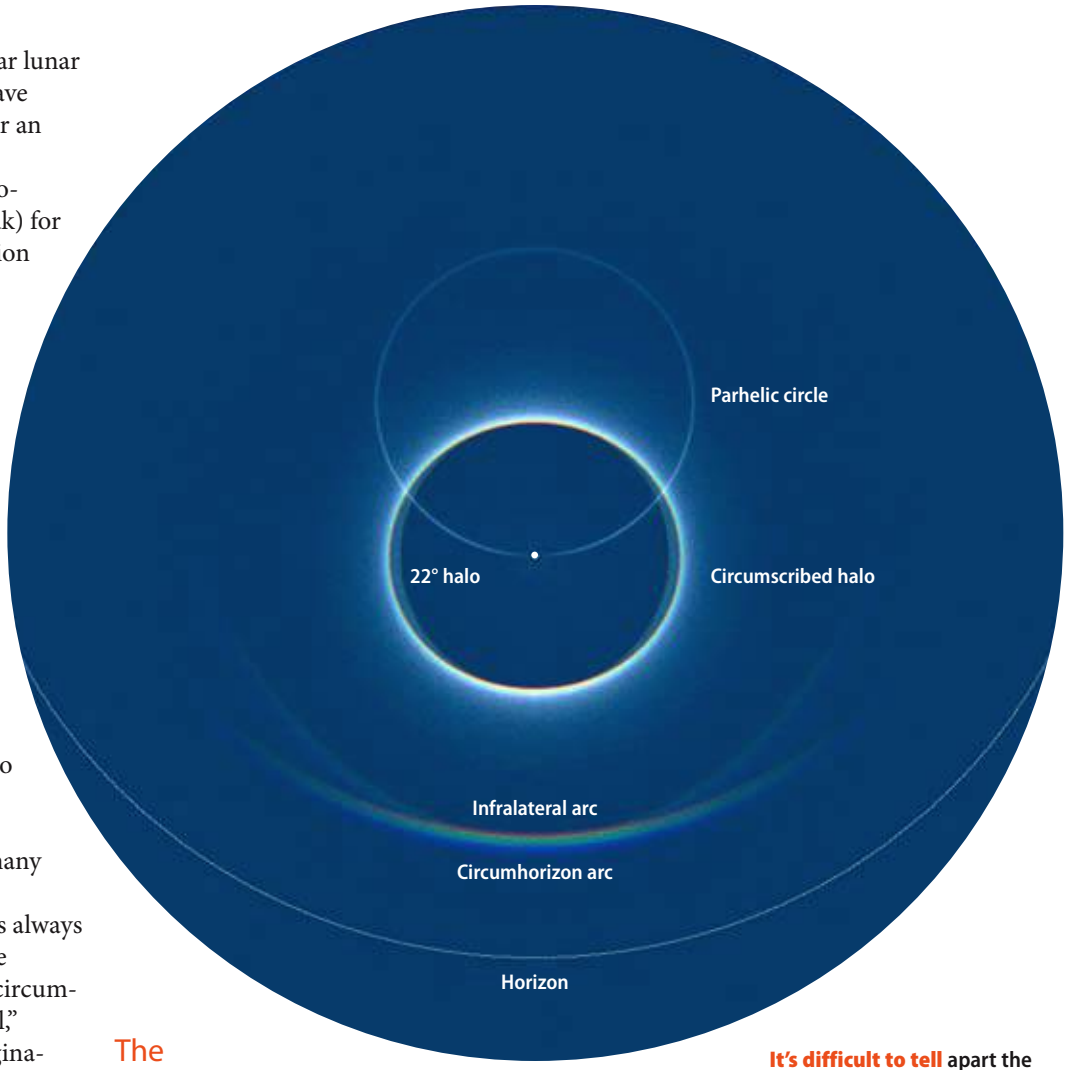
an altitude of 65°. At that particular lunar elevation, the lower band could have been either a circumhorizon arc or an infralateral arc.

I turned to Les Cowley of Atmospheric Optics (www.atoptics.co.uk) for help. He used a computer simulation to find clues as to which crystals made the display.

"The ring around the Moon could be a 22° halo from randomly oriented crystals or a circumscribed halo from horizontal columns," Cowley says. "My simulation shows both." The simulation also shows a bright parhelic circle, which, Cowley explains, is made by plate crystals and horizontal column crystals. "If the circular halo had been made by horizontal columns," Cowley deduces, "I would have expected to see some parhelic circle. But it is absent from the photograph. This suggests that there were not too many column crystals present."

What about the lower arc? "It is always difficult to say from a single image whether an arc in this region is a circumhorizon or high-Moon infralateral," Cowley says. "Using 'averted imagination,' there could be two halos."

"However," Cowley adds, "given the evidence that there were not many column crystals, I think we should say that an infralateral component is, as in Scottish jury verdicts, 'not proven.' There is more evidence for a circumhorizon arc." You can e-mail Tezel at canopia@yahoo.com.



It's difficult to tell apart the infralateral arc from the circumhorizon arc. This simulation shows how similar their positions are relative to a Full Moon and the horizon. The center dot is the Full Moon. Les Cowley

Look closely at open cluster NGC 2547, and you just might see a heart. In this image, north is to the left so the heart is easier to see. Guillermo Yañez

The Valentine Cluster

Those who have access to a southern horizon that allows for viewing stars to declinations south of –50° might want to turn their attention to open star cluster NGC 2547. It's a 5th-magnitude tangle of suns almost 2° south of magnitude 1.8 Gamma (γ) Velorum. Chilean amateur astronomer Guillermo Yañez tells us why.

"In January 2009, I was visiting a public amateur observatory in Santa Cruz [Chile]," Yañez says. "We were looking at several open clusters in the neighborhood of Puppis with a nice 18-inch Dobsonian when an anonymous amateur astronomer asked us to point the telescope to NGC 2547 in Vela. He then told us that through binoculars the cluster's brightest stars have the shape of a valentine heart."

When Yañez and everyone else saw the cluster though the Dobsonian, they all agreed: "It really does look like a valentine!" Yañez exclaimed. In fun, Yañez gave the younger male amateur astronomers at the observatory a piece of advice: "Fellow astronomers," he said, "the next time you bring your girlfriend on a stargazing trip, show her NGC 2547 and dedicate it to her. She may fall in love with you and the stars!"

With a declination of –49°14', NGC 2547 is a grass grazer as seen from much of the lower United States. But I highly suggest those attending a southern star party, such as February's Winter Star Party in the Florida Keys, to turn their attention to it. The celestial valentine is well-placed above the southern horizon between 9 and 10 P.M. You can e-mail Guillermo at contacto@guillermo.cl.

If you have observations of other curious phenomena, I'd like to hear about them. You can send them via e-mail to someara@interpac.net. And while I enjoy reading your responses, unfortunately I can't publish all of them.

Observing Basics

by Glenn Chaple

Cruise the Milky Way

Get out to a dark-sky site to observe the wonder of our home galaxy.

What is the most awe-inspiring sight in the night sky? Some would point to the Moon, with its rugged, cratered landscape that even the smallest telescope can bring to life. Others would suggest Saturn, the solar system's ringed marvel. Deep-sky enthusiasts might argue that the Orion Nebula (M42) is the universe's supreme sight.

Perhaps the most magnificent of all cosmic vistas is the one visible without any optical aid but sadly unavailable to urban (and many times suburban) dwellers — the Milky Way. Those fortunate enough to be in the countryside on a crisp, moonless late-summer evening can witness this glowing river of light arching north to south across the sky. It's the same mystical glow that dazzled early humans and inspired numerous myths and legends.

The late-summer Milky Way extends south through the constellation Sagittarius — the direction toward the heart of the galaxy. Viewing our galaxy on a clear, dark night from the countryside, observers can cruise a strip of some 2,500 visible stars. Gianni Tumino

One of my favorite late-summer activities is what I call a "Milky Way cruise." On a clear, dark evening, I settle into a reclining lawn chair, and gaze upward. As my eyes dark-adapt, the Milky Way looms larger and brighter. I pull out my binoculars and begin a lazy sweep up and down its length, from Cassiopeia in the north to Sagittarius above the southern horizon. There's nothing scientific about this cruise. I don't measure anything, nor do I try to identify and sketch each cluster or nebula I encounter. I simply lie back and take in a cosmic vista equal in majesty to Earth's Grand Canyon.

Galileo most likely spent many nights cruising the Milky Way. Unlike my excursions, his were every bit scientific. At the time, the makeup of the Milky Way was unknown — its nature the speculation of philosophers. Using his telescope, Galileo found the Milky Way to be "a congeries of innumerable stars grouped together in clusters. Upon whatever part of it the telescope is directed, a vast crowd of stars is immediately presented to view." Without knowing it, Galileo had discovered our galaxy.

We're 4 centuries too late to make such a groundbreaking Milky Way discovery, but we can still enjoy its grandeur. Plan a Milky Way cruise this month.

But what will the weather be like tonight? It's a question all astronomers ask (except, of course, those who engage in radio astronomy), and one especially important if observing includes a trip to a dark-sky site. For those of us who ply the visible part of the electromagnetic spectrum and would like to enjoy a Milky Way vista, clouds or a turbulent atmosphere can spoil the sky show. Knowledge of current and impending weather patterns is indispensable for planning an evening observing session.

A great source of up-to-date weather information is the Internet. So, I've collected a list of three sites you might want to try:

The simplest of the trio, Intellicast.com provides a map of cloud cover for the United States, southern Canada, and northern Mexico from its "Sky Watch" page (located in the "National Outdoors" section). Predictions for the next 24 hours appear in 6-hour increments.

Rather than portraying weather conditions on a standard map, ClearDarkSky.com displays weather factors graphically in a series of hourly blocks, which are very popular with Astronomy.com Forum users. ClearDarkSky.com covers the same area as Intellicast.com. You can receive weather data specific to your locale for a period of nearly 48 hours. Besides cloud cover, ClearDarkSky.com delivers information on seeing and transparency, darkness, wind, humidity, and temperature.

The new kid on the block, SkippySky (skippysky.com.au) is the collaborative brainchild of Australians Andrew Cool and Dr. Robert Dahni. SkippySky is more global than the other two sites — it includes information for Europe, Australia, and New Zealand, parts of Africa and South America, as well as North America. Weather maps covering 3 days in 3-hour intervals include data on cloud cover, seeing and transparency, jet stream activity, risk of dewing, wind, temperature, and pressure.

Next time you want the lowdown on Milky Way observing weather (or any observing weather, for that matter), you'll know of a few sites where you can look.

Questions, comments, or suggestions? E-mail me at gchaple@hotmail.com. Next month: a Galilean miss. Clear skies!

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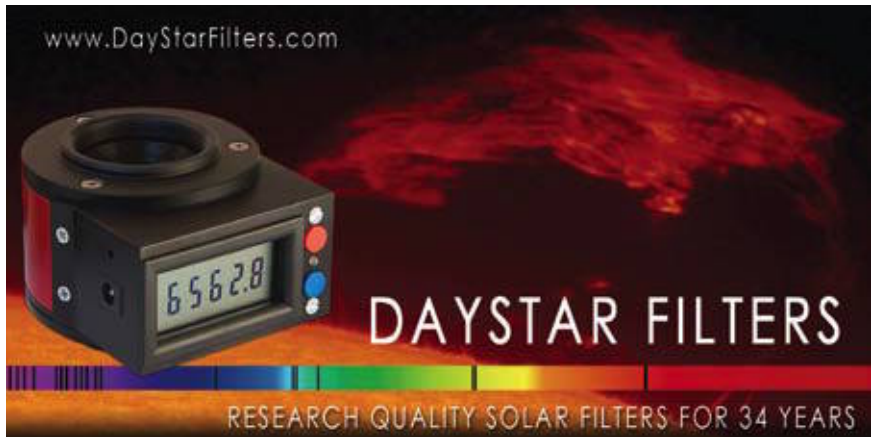

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Vic Maris

President, Stellarvue

Vic Maris is living the California dream. He was born in Burbank and built telescopes as a child. He lived near some of the industry's best telescope-makers. "When I made my first mirror, I had many mentors," he says.

Among them were Tom Cave from Cave Optical Company, Dick Nelson from Optical Craftsman Telescopes, and Jim Jacobsen of Coulter Optical Company. Each of them patiently showed Maris different telescope-making techniques. At the age of 16, Maris completed his first 5-inch refractor.

Then he went off into the woods, literally. Maris spent 30 years working for the California State Park system. As Chief Ranger for Sonoma County State Parks, he assisted local astronomy clubs and enabled them to build and operate the Robert Fergusson Observatory at Sugarloaf Ridge State Park. "That project was a testament to what dedicated, hard-working amateur astronomers can do if given the opportunity," he says.

Maris then returned to his first love: telescope-making. In 1997, he started Stellarvue. At the time, he worked out of his garage. The company is bigger now, but Maris still star tests every telescope he sells.

Vic Maris shows off the Zygo Mark IV interferometer, a $150,000 machine Stellarvue uses to test its telescopes. Photo courtesy Stellarvue

We as manufacturers must embrace the notion that the way to maintain interest in this endeavor is to make high-quality equipment and provide memorable experiences.

Tell me about the most popular products you have on the market.

Our apochromatic triplets like the SV90T, the SV105, and the SV115T and our ED doublet refractors have become our most popular telescopes.

What is something cool about Stellarvue that few people know?

Stellarvue is not just a telescope company. We also offer astronomy outings and educational programs. We recently started up the Stellarvue Allstars, a club exclusively for Stellarvue owners.

We offer our Allstars prototypes and one-of-a-kind items, and they have the first opportunity to sign up for our Stellartrips and astronomy courses. We make the finest refractors, but we are also committed to providing education and connecting people who share an interest in this hobby.

How has Stellarvue changed through the years?

Computer numerical control (CNC) machines and advanced test equipment have made a significant difference at Stellarvue when it comes to telescope-making. What has not changed is our mission to provide high-quality telescopes, programs, and experiences.

Do you enjoy observing?

Astronomy is my passion. Having the opportunity to take one of my telescopes out under a pitch-black sky and soar among the stars is what recharges my batteries. Jupiter is my favorite planet because it is always changing. Watching festoons, plumes, and whirls move across the cloud tops and then one or more satellite disks transiting never fails to amaze me.

Can you share anything about upcoming new products from Stellarvue?

We have a new line of dedicated photographic field flatteners. Each of these will provide an astroimager with a completely flat field of view. Our large flatteners are a perfect match for the largest-chip CCD cameras on the market.

Where, in your opinion, is the hobby headed?

Amateur astronomy is undergoing a paradigm shift. There are many competing interests in today's market, including video games and the Internet. Astronomy is a more pastoral endeavor that appeals to some but not all. Through all of this, people will continue to be drawn to the stars, and others can be shown the wonders of the night sky.

We as manufacturers must embrace the notion that the way to maintain interest in this endeavor is to make high-quality equipment. That equipment, in turn, will provide memorable experiences.

When people are disappointed, they move away from astronomy. All industry leaders must do what they can to keep our hobby interesting and vital.

INDEX *of* ADVERTISERS

Adirondack Video Astronomy 78
ADM 78
Adorama 15, 23
Ash Manufacturing 75
Astro Haven 78
Astro-Physics 77
Astrodon 77
Astronomics 4
Astronomy magazine 72
Astronomy Technologies 76
Astronomy.com 73
Astrotelescopes 78
Aurora Astro Products, LLC 78
Beam of Light Technologies 77
Beta Electronics 78
Bob's Knobs 78
Celestron 7, 9
Daystar Filters 73
Denkmeier Optical 78
Glatter, Howard 76
Hubble Optics 78
Jewelry Designs For Men 78
Jim's Mobile, Inc 13
Khan Scope Centre 78
Lightbuckets.com 3
Majestic Optical Coatings 78
Maxson Technologies 78
Meade Instruments Corporation .. 20, 21, 22, 82
Morehead State University 71
New Mexico Southern Skies 76
Newport Glass Works 77
Observatory, Inc., The 78
Obsession Telescopes 77
Oceanside Photo & Telescope 71
Optic Wave Laboratories 78
Optical Mechanics, Inc 77
Orion Telescopes & Binoculars 5
Owl Services 78
Printmakers, Inc 77
Rainbow Symphony 78
Scope Buggy 77
Scope City 76
ScopeStuff 78
SCS Astro 78
Sirius Observatories 77
Solarscope 78
Space Law Academy 78
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Starmaster Portable Telescope 78
Stellarvue 76
Teaching Company, The 17
Technical Innovations 73
Tele Vue Optics, Inc 2
Travel Quest International 67
Vixen Optics 81
Woodland Hills Cameras & Telescopes 75
www.bigbinoculars.com 77

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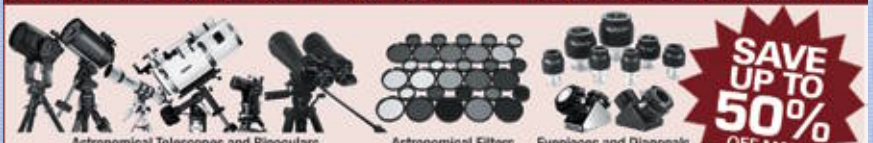

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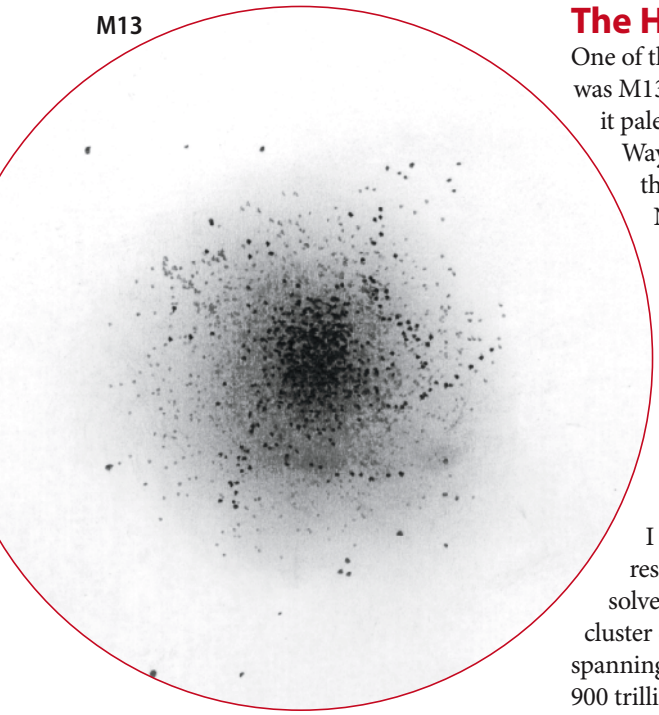
Deep-sky Showcase

Each month, Astronomy *Editor David J. Eicher, founder and editor of the late* Deep Sky *magazine, will bring you the story behind two favorite deep-sky objects for backyard observers. Along with photos, he'll also present sketches he's made over the past 33 years.*

The Hercules Cluster and M83

by David J. Eicher

M13



The Hercules Cluster sketched by David J. Eicher using a 17.5-inch f/4.5 reflector at 142x.

The Hercules Cluster (M13)

One of the first sky objects I ever looked at was M13, the Hercules Cluster. Although it pales in comparison to the Milky Way's best globular, Omega Centauri, the Hercules Cluster is a favorite for Northern Hemisphere viewers because of its height in the sky amid the easily recognizable "keystone" asterism in Hercules.

Visible to the naked eye as a tiny spot of light, the cluster is a fuzzy little ball in binoculars but really comes into its own through 6-inch or larger scopes. In a 17.5-inch Dobsonian at 142x, I saw a swarming mass of nicely resolved stars over a huge, unresolved gray-green mass of light. The cluster contains nearly a million stars spanning a gulf of 150 light-years, some 900 trillion miles. Inside the Hercules Cluster, you would see lots of widely spaced bright stars. When viewing M13 with a 6-inch or larger scope, look for the little galaxy NGC 6207, a 12th-magnitude edge-on spiral, 28' to the northeast. Larger scopes can reveal the obscure galaxy IC 4617, a magnitude 15.2 object, between NGC 6207 and the cluster.

M13

Bob and Janice Fera

Designations: M13, NGC 6205
Position: 16h42m, 36°28' (2000.0)
Constellation: Hercules
Magnitude: 5.8
Size: 16.6'
Distance: 25,100 light-years

M83

R. Jay GaBany

Designations: M83, NGC 5236
Position: 13h37m, –29°52' (2000.0)
Constellation: Hydra
Type: Barred spiral galaxy
Magnitude: 7.9
Size: 12.9' by 11.5'
Distance: 14.7 million light-years

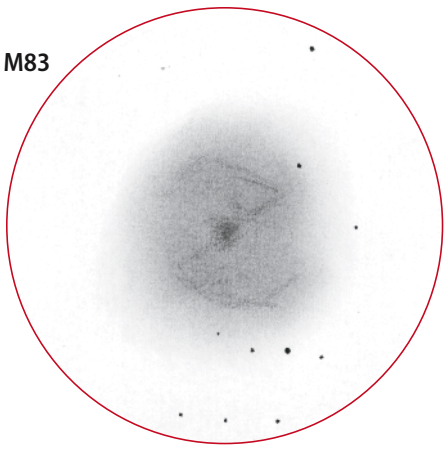
Spiral galaxy M83

Sometimes called the Southern Pinwheel Galaxy in the mania to give everything in the sky a popular name, M83 has been a popular target on the galaxy-observing list for years. Tucked down low in the constellation Hydra, this showpiece requires a dark southern horizon to be enjoyed.

Visible almost face-on to our line of sight, M83 appears bright and spectacular because it's close to us — less than 15 million light-years away in the M83/Centaurus A group of galaxies. For many years M83 was classified as an Sc galaxy; recently, it's been classed as a modified barred spiral. The galaxy produced six bright supernovae between 1923 and 1983.

An 8-inch scope at 50x shows M83 as a circular glow with hints of spiral structure and a moderately condensed nucleus. The galaxy lies in a rich, pretty star field. Observers with larger scopes will see much more detail in M83's arms, particularly on dark moonless nights.

M83



Barred spiral galaxy M83 sketched by David J. Eicher using an 8-inch f/10 SCT at 50x.

The Cosmic Grid

All things high, low, weird, and wonderful in astronomy and space science. **by Daniel Pendick**

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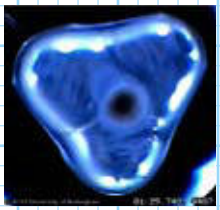


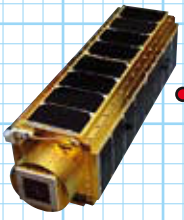
Tabletop black hole
British physicists Richard Hill and Laurence Eaves spin a magnetically levitated water droplet 3 times per second, exploring similarities between the shapes of black holes and whirling water.

Get real
French physicist and philosopher Bernard d'Espagnat wins the $1.4 million John Templeton Foundation prize for thinking deep thoughts about science's limited power to understand reality.

Giant sucking sound
Harvard astrophysicists discover something even more terrifying than global economic collapse: Hundreds of bachelor black holes may wander the Milky Way Galaxy.

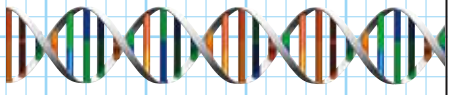
The Great Pumpkin
Pumpkin-shaped superpressure balloons will soon loft astrophysical instruments to the edge of space (20 miles high) for up for 100 days.

Geomagnetic apocalypse
A National Academy of Sciences report says a solar superstorm could knock out the national power grid and trigger an economic and public health crisis that would take a decade to recover from.



A toast to innovation
NASA's 10-pound, breadloaf-sized "nanosatellite" PharmaSat does drug research on a down-to-earth budget.

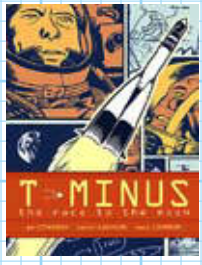
Saturn V flies again
Master model rocketeer Steve Eves' 36-foot-tall Saturn V soars to over 4,000 feet after launch from Higgs Farm in Price, Maryland, on April 25; it deploys chutes and lands upright.



Grave research
Italian scientists want to exhume the body of Galileo Galilei to acquire DNA samples and figure out what caused the 17th-century astronomer to lose his vision.

One more time, Carl
The free TV webcasting site Hulu.com posts the entire *Cosmos* series.

Comic effect
Jim Ottaviani's graphic novel *T-minus* tells a gripping history of the Space Race with underground-style cartooning by Zander Cannon and Kevin Cannon.



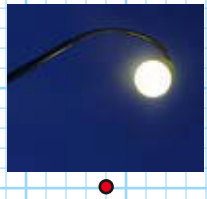
X-chief
After resigning as NASA's science chief, S. Alan Stern signs on as science mission director for the private firm Odyssey Moon, one of 16 teams competing for the Google Lunar X prize.

Do-it-yourself satire
Astronaut Andrew Thomas posts a 10-minute satirical video on YouTube spotlighting ingrained behaviors at NASA's Johnson Space Center that squelch innovation.

Tom Hanks, co-star Ayelet Zurer, director Ron Howard

Star turn
While touring CERN to promote *Angels & Demons*, Tom Hanks offers to turn the laboratory's ailing Large Hadron Collider back on after repairs.

A Moon too far
The first version of the movie poster for *Moon* cites a distance to the Moon of 950,000 miles — 4 times the actual distance.



Night light
More than one-fifth of the world population can no longer see the Milky Way with the naked eye, according to astronomer Connie Walker of the National Optical Astronomy Observatory in Tucson, Arizona.

Boss speaks
"I think it's inevitable that there are earth-like planets out there. I suspect that every star we look at in the night sky has an earthlike planet around it." — Alan Boss of the Carnegie Institution of Washington.

PHOTOGRAPHS: Richard Hill & Laurence Eaves (spinning droplet); John Templeton Foundation (Bernard d'Espagnat); NASA (pumpkin balloon); NASA/ARC/Christopher Beasley (PharmaSat); Mark Canepa (Saturn V); David A. Aguilar/CfA (roaming black hole); ©2009 Jupiterimages Corporation (solar storm); *Astronomy*: Roen Kelly (DNA); Andrew Thomas/YouTube (satirical video); Ain't It Cool News/www.aintitcool.com (Moon poster); ©2009 Jupiterimages Corporation (street light); Jim Ottaviani/Zander Cannon/Kevin Cannon (T-minus); CERN/Maximilien Brice/Claudia Marcelloni (Tom Hanks); Alan Boss (Alan Boss)

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